Navy Experimental Diving Unit
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TA98-030
NEDU TR# 3-00
29 Jun 00

NAVSEA 00C5 DESIGNED GROUND FAULT INTERRUPTER BREADBOARD AND PROTOTYPE TEST AND EVALUATION

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<Unclassified>
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UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified			1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited	
2b. DECLASSIFICATION/DOWNGRADING AUTHORITY				
4. PERFORMING ORGANIZATION REPORT NUMBER (S) NEDU Technical Report No. 3-00			5. MONITORING ORGANIZATION REPORT NUMBER (S)	
6a. NAME OF PERFORMING ORGANIZATION Navy Experimental Diving Unit	6b. OFFICE SYMBOL (If Applicable)		7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State, and ZIP Code) 321 Bullfinch Road, Panama City, FL 32407-7015			7b. ADDRESS (City, State, and Zip Code)	
8a. NAME OF FUNDING SPONSORING ORGANIZATION Naval Sea Systems Command	8b. OFFICE SYMBOL (If Applicable) 00C		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code) 2531 Jefferson Davis Highway, Arlington, VA 22242-5160			10. SOURCE OF FUNDING NUMBERS N0002400WR01028	
		PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO. 98-030	WORK UNIT ACCESSION NO.

11. TITLE
NAVSEA-00C5 DESIGNED GROUND FAULT INTERRUPTER BREADBOARD and PROTOTYPE TEST and EVALUATION (Unclassified)

12. PERSONAL AUTHOR (S)
JERRY D. PELTON

13a. TYPE OF REPORT Technical Report	13b. TIME COVERED FROM 1998 TO 2000	14. DATE OF REPORT (Year, Month, Day) 2000, 05, 22	15. PAGE COUNT

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and Identify by block number)
FIELD	GROUP	SUB-GROUP	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This test and evaluation covered the development of a Navy designed portable ground fault interrupter from breadboard to finished prototype. Testing included design review, bench testing, and environmental testing. Changes were made to the design along the way to improve or correct areas were problems were found. The final prototype version was tested in accordance with sections of MIL-STD-810E determined to represent conditions this equipment would be operated within. Results of this effort is a design that is ready for production with only minor changes to correct for problems found during final testing.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED/UNLIMITED X SAME AS RPT. DTIC USERS	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
NEDU Librarian	904-230-3100	

UNCLASSIFIED

DD Form 1473

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ABSTRACT

This test and evaluation covered the development of a Navy designed portable ground fault interrupter from breadboard to finished prototype. Testing included design review, bench testing, and environmental testing. Changes were made to the design along the way to improve or correct areas where problems were found. The final prototype version was tested in accordance with the sections of MIL-STD-810E determined to represent conditions this equipment would be operated within. The result of this effort is a design that is ready for production with only minor changes to correct for problems found during final testing.

INTRODUCTION

After extensive market research, it was determined that none of the commercial portable ground fault interrupters meet the Navy requirements for this equipment. Therefore, Naval Sea Systems Command (NAVSEA 00C5) set out to design a system that would meet the requirements which would subsequently be built under contract for use by Navy diving commands. The Navy Experimental Diving Unit was tasked to review the design, test breadboard equipment, and finally test the prototype versions.

METHODS

GENERAL

Phase 1

(a) Reviewed Test Plan written by Battelle Memorial Institute and provided comments and recommendations back to NAVSEA 00C5. Submitted Test Plan approved by Commanding Officer of Navy Experimental Diving Unit (NEDU), for review by NAVSEA 00C5. Both Test Plans were modified into one and approved by NAVSEA 00C5.

(b) Breadboard version of Navy design was built by NAVSEA 00C5 and shipped to NEDU for testing. During testing, problems were found and corrected by both NEDU and the designer. Breadboard version was finalized and design was submitted by NAVSEA 00C5 to build prototype versions.

Phase 2

(a) Prototype versions were completed and shipped to NEDU for testing. NEDU conducted bench testing of two units and placed Naval Coastal Systems Station (CSS) under contract to conduct environmental testing in accordance with the test plan, which was in accordance with MIL-STD-810E.

(b) Both prototype units failed portions of the environmental testing, and were shipped back to NAVSEA 00C5 for modifications.

(c) When modifications were made, the units were returned to NEDU and testing was re-started from the beginning.

(d) The order of testing was changed for the second series of testing. The Rain Test was conducted first, to determine if the leakage problems had been solved, and the Low and High Temperature Operational Tests were conducted to meet personnel schedules.

EXPERIMENTAL DESIGN AND ANALYSIS

The objective of this effort was to test and evaluate a ground fault interrupter designed to meet Navy requirements. This type of equipment must provide a high level of electrical safety to operators of portable electrical devices in and around water.

Test Parameters

(a) Bench testing was conducted to confirm that trip times and leakage trip point were within specifications, time less than 20 milli seconds (ms) with a leakage of 10 milli amps (ma) to ground. These tests were conducted with utility power and simulated shipboard power. Testing was conducted on each line lead 5 times and the average of the trip times taken for the overall value. The NEDU-designed GFI Tester was used to provide input power and to introduce the fault current using the built-in decade resistance box, each line lead was tested according to its voltage level above reference ground.

(b) Evaluation of the ergonomics of the prototypes including the alignment/setup procedure was conducted.

(c) Resistive and inductive overload tests were conducted on both units.

(d) Environmental testing was conducted per MIL-STD-810E:

- High Temperature, (Operational) Temp: +48°C (118.4°F) for 48 hours.
- Vibration Method, 514.4, Category 1, without shipping container.
- Rain: Place the GFI unit in the test area in the upright, operational position, with the required input and output wiring connected. Operate the unit during the test, and manually or automatically trip minimum of once every 20 minutes during the test. Expose the unit to an overlapping spray pattern where the nozzles are placed 19 inches from the test surface. The droplets to be approximately 2 to 4.5 mm and sprayed at a minimum pressure of 40 psig. Expose the unit to this environment for a minimum of 40 minutes for each exposed face.
- Low Temperature (Operational): Place the units in the operational condition, within the temperature chamber. Set chamber temperature to –31 °C (-23.8°F), maintain at that temperature for a minimum of 8 hours. During the test, trip the unit using the internal tripping circuit. Trip and reset a minimum of once per hour throughout the test.
- Low Temperature/Transit Drop Test. This test combines the effects of low temperature storage with the potential for being dropped during transit. Place the units within a temperature chamber and maintain at –31 °C (-23.8°F) for a minimum of 24 hours. After the 24 hours, subject the units to the Transit Drop Test. Suspend the units 48 inches above a 2-inch thick plywood surface backed by concrete. Drop Unit 1 a total of six times, once on each face. Drop Unit 2 on six of eight corners.

EQUIPMENT AND INSTRUMENTATION

Bench Testing (Enclosure 1)

- GFI Tester (NEDU Device)
- Digital Volt Meter- Fluke 87
- Oscilloscope – Tektronix Model 222
- Resistive Load and Inductive Load

Environmental Testing (Enclosure 2)

- Test Chambers (hot and cold)
- Vibration Table
- Transit Drop Device
- Spray Nozzle Array (Rain Test)

PROCEDURES

Bench Testing

Ground Fault Interrupter Tester Circuit Operation:

Use of the ground fault tester requires that the technician be familiar with the operation of a digitizing oscilloscope such as the Tektronix model 222 used in this test procedure. The ground fault tester derives its power from 110-130 VAC 60 Hz which is input at the plug labeled "115 VAC INPUT." This voltage is coupled through a one-to-one isolation transformer, and the isolated 110-130 VAC is available at the socket labeled "GFI POWER." The power supply cord of the ground fault interrupter being tested is plugged into this socket. The output of the ground fault interrupter is connected to the plug labeled "GFI OUTPUT." The circuit breaker on the front panel doubles as an on/off switch. The three-position (center off) switch labeled "L1" and "L2" selects the line upon which the ground fault will be placed. This switch is left in the center position until all other connections are complete including the oscilloscope probe leads. Channel 1 of the oscilloscope is connected to the jacks labeled "L1" and "L2." Attach the signal probe to the same voltage leg which will have the ground fault applied and the ground clip of that probe to the other voltage leg. Channel 2 of the oscilloscope is connected to the jack labeled "TRIG" and the ground lead of the probe is attached to the jack labeled "G."

The Digital Storage Oscilloscope is configured as follows:

1. CH1 50-volts/division CH2 10 volts/div
2. CH1 AC coupling CH2 DC coupling
3. Trigger source - CH2
4. Trigger mode - SSEQ
5. Trigger slope - +
6. Trigger level - 4 volts
7. Trigger Pos - MID
8. Horizontal - 5ms/division

After configuring the oscilloscope press the "CLEAR" button. Then press the "INIT" button. This arms the sweep circuit of the scope and the instrument will wait for a trigger on channel 2.

With all connections complete and the L1 - L2 switch in the center position, place the circuit breaker in the ON position and verify that the power lamp is lit. Select the value of the ground fault resistance on the decade box. Now select L1 or L2 on the switch. Placing the switch in either position inserts the ground fault resistance while simultaneously starting the sweep on the oscilloscope. If the ground fault leakage is of sufficient value, the ground fault interrupter should react, shutting off the output.

Channel 2 of the oscilloscope should display a positive pulse the leading edge of which is the start of the measured reaction time. Channel 1 will display an AC sine wave (the output of the ground fault interrupter), which will cease at the moment the ground fault interrupter turns off its output. The interval between the leading edge of the pulse on Ch 2 and the shutoff of the AC voltage on Ch 1 is the reaction time of the ground fault interrupter.

Ergonomics Evaluation

Prototype Units were evaluated for ease of operation, viewing of nametags, and ability to hear or view alarms. Also evaluated were ease of repairs and troubleshooting (Note: this review was limited, due to the lack of material available, and should be improved on the production models).

Load Testing

Each prototype unit was tested to determine if overload trip devices functioned properly. This test was conducted by increasing a resistive load until the unit overload device tripped, while monitoring input and output amperage. Also, an overload/run test was conducted using a 1.5 horsepower motor. This motor has a normal load equal to 100 percent of the GFI unit being tested. Energize the GFI and then start the motor, then add load to the motor until a GFI overload occurs.

Environmental Testing

Environmental testing was conducted per MIL-STD-810E using the following methods:

- High Temperature, Method 501.3, Procedure 2. Max Temp = +48°C (118.4°F). Upon completion of test the units were bench tested to ensure trip times had not been affected by this environmental test.
- Vibration Method, 514.4, Category1, Basic Transportation, without shipping container. Upon completion of test the units were bench tested to ensure trip times had not been affected by this environmental test.
- Rain, Method 506.3, Procedure III. The GFI was placed in the test chamber in the upright, operational position, with the required input and output wiring connected. The unit was operating during the test, and was manually or automatically tripped at a minimum of once every 20 minutes during the test. The item was exposed to an overlapping spray pattern where the nozzles were placed 19 inches from the test surface. The droplets were approximately 2 to 4.5 mm, and sprayed at a minimum pressure of 40 psig; the item was exposed to this environment for a minimum of 40 minutes for each exposed face. Upon completion of test the units were bench tested to insure trip times had not been affected by this environmental test

- Low Temperature, Method 502.3, Procedure II. The unit was placed, in the operational condition, within the temperature chamber. The chamber temperature was lowered to
  -31 °C (-23.8°F) stabilized. Once the unit was stabilized, it was maintained at that temperature for a minimum of 8 hours. During the test, the unit was "tripped" using the internal tripping circuit. The unit was "tripped" and reset a minimum of once per hour throughout the test. Upon completion of test the units were bench tested to insure trip times had not been affected by this environmental test.
- Low Temperature/Transit Drop Test. This test combined the effects of Low Temperature Storage with the potential for being dropped during transit. The units were placed in a chamber maintained at -31 °C (-23.8°F) for a minimum of 24 hours. After the 24 hours the units were subjected to the Transit Drop Test as specified in MIL-STD-810E, Method 516.4, Procedure IV. The units were suspended 48 inches above a 2-inch thick plywood surface backed by concrete. Unit 1 was dropped a total of six times, once on each face. Unit 2 was dropped on six of eight corners. Upon completion of test the units were bench tested to insure trip times had not been affected by this environmental test.

RESULTS

TESTING OF THE BREADBOARD VERSION

The NAVSEA Designed Breadboard Ground Fault Interrupter (GFI) appeared to be well designed with an isolation transformer and fault circuitry to detect current overload and low voltage, in addition to ground fault detection and circuit interruption. The GFI was set up and adjusted in accordance with the provided instructions. The unit contained a test circuit that cycled the GFI and allowed the phase angle of the fault trip point to be varied between 0 degrees and 180 degrees. The unit also provided indicator lamps and alarms for status and warnings, showing conditions such as low input voltage and current overloads.

When using the built-in testing circuit, the phase angle adjustment did not allow a full 180 degrees of trip points. This was most likely due to the low fault current when the voltage was near zero volts AC, during that phase of the AC power. In addition, when using the built-in test circuit, the output would sometimes remain energized while still indicating a fault trip. This was assumed to be a problem with the test circuit and not the actual GFI hardware. The test circuit was disconnected, and the GFI was manually tested over 100 times without this error occurring.

The output of the GFI would turn off at the zero voltage crossing point. Thus, the maximum time from fault detection to interrupt was approximately 1/60th of a second, or 16.7 milliseconds.

The current overload detection circuit was not tested. The low volt detection was partially tested by reducing the input voltage, the low voltage audio alarm sounded at about 90 VAC.

The breadboard GFI as tested is large and bulky with a large heat sink and transformer. These two items will cause the final design to be large and not easily portable. While the transformer size is necessary to carry the load, the heat sink could be made an integral part of the container, which would reduce the size. The test circuit adds to the overall complexity of the design, and while it is useful during this type of testing, we felt it should not be part of the final design.

TESTING OF THE PROTOTYPE VERSION

Bench Testing

- Average ground fault trip times on both prototype units were less than 20 ms at 10-ma leakage (Enclosure 1).
- Overload, high and low voltage tests were conducted on both prototype units prior to environmental testing. Both units operated within design specifications.
- Ground fault interruption testing, using the NEDU procedure, was conducted prior to start of the environmental testing and upon completion of each phase of the environmental testing.
- After the final environmental test (Transit Drop) both units were inspected and found to be non-operable due to disconnected connectors. These connectors were reconnected, units were checked for shorts, opens and grounds, and none were found. Both units were then tested using the built-in test circuit and using the NEDU procedure, found to be operational, although both had damaged components that will require repair or replacement.

Ergonomic Evaluation

- All switches were easy to operate under normal conditions; the only problem experienced was during the cold environmental testing. The rubber boot on the test trip switch was hard to operate under this condition, but was operable if held in place for a short period.
- All name tags were easy to read under normal lighting conditions, and were acceptable in low light conditions.
- Audible alarms could be heard under normal working conditions with background noise levels below 85 dBa.
- Visual alarms can be seen under normal and low light levels. However, they may be difficult to see in bright sunlight; this does not pose a problem if operators check the unit prior to starting a dive.

- The covers on the receptacles have retainer chains that have a tendency to break allowing the covers to be misplaced. This will need close attention, also in order for the unit to be rain/splash proof, the proper mating plugs must be used. These should be provided with the units when they are issued.
- The trip device fuse is located inside, at the bottom of unit, and is difficult to check and/or replace; also this location can cause the fuse to fail due to heat build up in high temperature operating conditions.
- The internal connectors have a tendency to disconnect due to the strain on them; adding to the length of wiring and using connectors that have positive latching could solve this.
- Troubleshooting these units was difficult due to the lack of information. There are test points but no data were provided for the values. Also there were some minor differences between the schematics and the as-built units circuits.

Environmental Testing

- The environmental testing was conducted by Coastal Systems Station, Dahlgren Division, Naval Surface Warfare Center. Details of this testing are covered by their report, ELPR-2000-02 (Enclosure (2).
- During the Rain Test, the receptacles leaked when the proper connectors were not used. Since the proper connectors were not available, two of the receptacles were replaced. The Woodhead p/n 60W47 receptacles with mating connector were used. Later the proper connectors were made available for the original Appleton receptacles, they were installed and the rain test was repeated. With the proper connectors both types of receptacles passed the rain test.
- During the High Temperature portion of the first series of environmental testing, the fuse for the trip device for both units failed. This failure was due to heat build-up within the units; the fuses in the prototype design were 1/8 amp. To meet the load requirements including the thermal load, this fuse was changed to a 1/4 amp fuse. This failure did not recur with the 1/4 amp fuse. During the first Vibration Test, the internal connectors disconnected. This occurred due to stress (spring action) on the wiring and the type of connectors (non-latching). When the units were returned to NAVSEA 00C5 for repairs these connectors were replaced by the type with a latch. These passed the second Vibration Test, but disconnected when they were subjected to the Transit Drop Test.

DISCUSSION

This equipment is designed to increase safety while portable electrical equipment is used in or around water. During the testing of the breadboard and prototype GFI, a number of design changes were made to improve the performance and reliability of the design. The design is very complex and will require trained technicians to maintain it. Only preliminary schematics were provided during this phase of the testing. A number of ergonomic deficiencies were noted during this evaluation that should be incorporated into the final design. The recommended changes to the NAVSEA 00C5 GFI are:

- Use backing nuts or nut-inserts to hold the receptacles in place.
- Make sure internal wiring does not have bend ratios that will cause insulation cracks during operation in cold weather or storage.
- Size fuses for operating current and thermal loads during operation at full load in high temperature conditions.
- Make sure operating instructions include caution concerning use of proper connectors during rain or other very wet conditions.
- Recommend that the power supply cable be brought into the housing via a 90° stuffing tube with cable angled towards the hinge side.
- Replace retainer chains with a cable.
- Relocate trip device fuse.
- Increase the length of wire on the internal connectors and use positive latching on the connectors.

When this equipment goes into the production phase, there must be very detailed schematics and troubleshooting guides produced, with complete test point values included.

CONCLUSIONS

The prototype NAVSEA 00C5 Ground Fault Interrupter performed adequately. Only minor ergonomic design changes are necessary when the unit goes into production. Functional testing of the production model is not required.

TO: D. S. GRAY

26 Aug 1998

From: Larry Gene Gibbs Jr.

Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the 1998 NAVY DESIGN BREADBOARD VERSION GFI Ground Fault Interrupter (GFI). Conduct test in accordance with NAVXDIVINGU 3960.3.

2.0 Device under test:

NAVY DESIGN BREADBOARD (GFI)
Model: N/A
Ser.#: N/A

3.0 Test equipment:

1. GFI tester	NEDU in-house device	
2. Voltmeter	Fluke model 87	Cal due Nov. 20, 1999
3. Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFISETUP.DWG.
2. Power up system, connect 50 watt light bulb to GFI output.
3. Using the GFI tester induce a 210 ohm resistance to create a fault path between the L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.2 K ohm resistance to create a fault path between the L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test	Navy Design Breadboard	Results
L1 to Ground	Passed	7.44 ms (avg)
L2 to Ground	Passed	6.56 ms (avg)

Comments:

- GFI PASSED the test criteria
- Measured 2.1 volts between L1 (black) and ground
- Measured 111.5 volts between L2 (red) and ground
- Fault resistance = (voltage / .01 amps)

Larry Gene Gibbs Jr.
Test Technician

ENCLOSURE (1)

1998 Navy design breadboard GFI Reduced Data

Measured voltages at GFI output-

Not tripped	**Voltage**
L2 (red) - L1 (black)	111.5 volts
GND - L2	112.8 volts
GND - L1	2.1 volts

Tripped	**Voltage**	**Short Circuit Current**
L2 (red) - L1 (black)	26.8 mV	approx 1.3 microamps AC
GND - L2	52.9 volts	approx 233 microamps AC
GND - L1	53.6 volts	approx 234 microamps AC

L1 - GND fault-

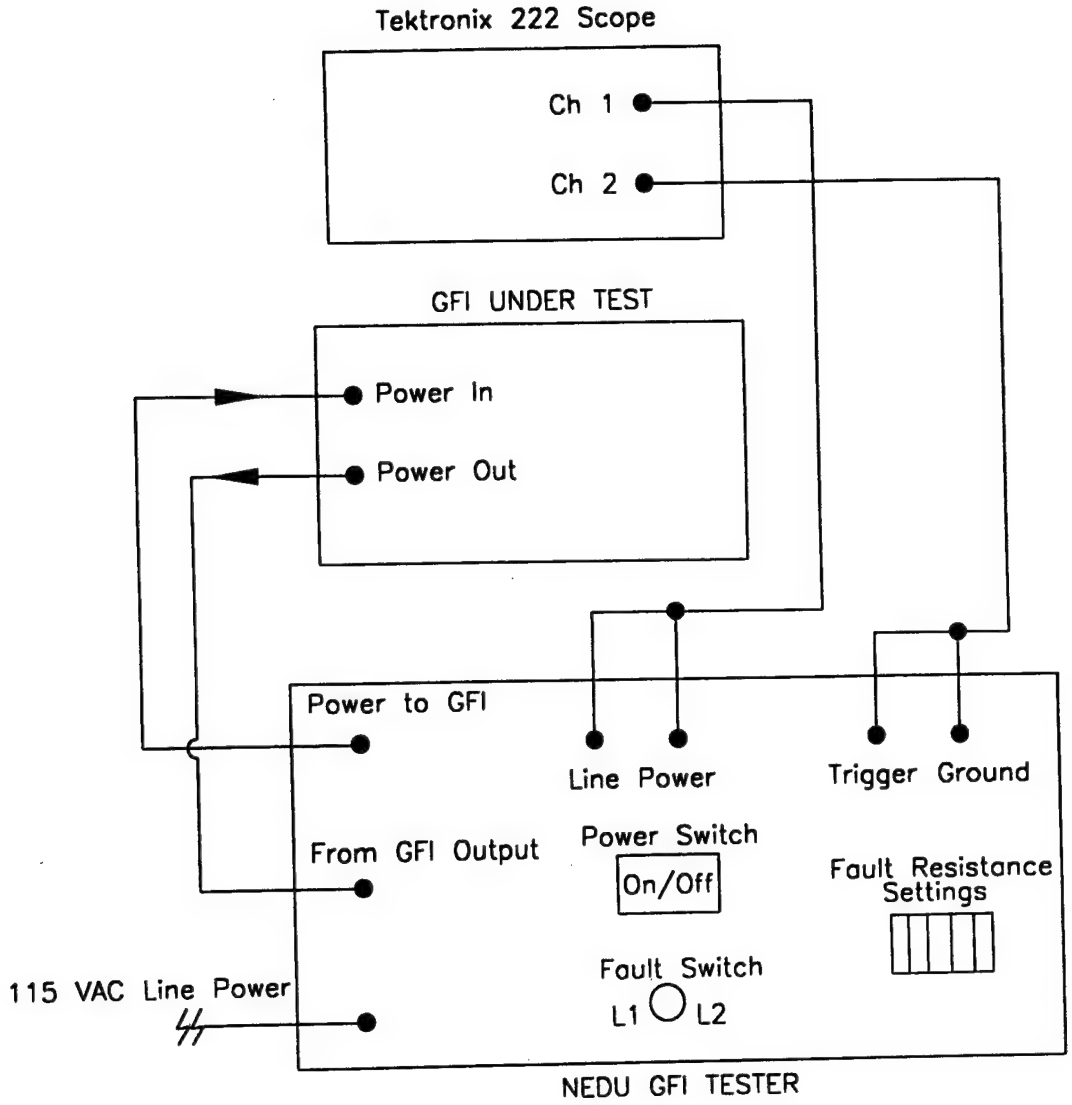
Consistently triggered with faults less than 345 ohms.
Would not trigger with faults greater than 400 ohms.

L2 - GND fault-

Consistently triggered with faults less than 29K ohms.
Would not trigger with faults greater than 34K ohms.

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 210 ohm fault	L2 trigger time - 11.2k ohm fault
10.2 ms	8.7 ms
6.0 ms	6.0 ms
3.7 ms	9.8 ms
12.4 ms	4.7 ms
4.9 ms	3.6 ms
AVG	AVG
7.44 ms	6.56 ms



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TITLE GROUND FAULT INTERRUPTER TESTING EQUIPMENT SETUP

DWG NO.	REV	DATE	SHEET
GFISETUP.DWG	A	2/19/98	1 OF 1

GROUND FAULT INTERRUPTER (GFI)*
TEST DATA REPORT

EQUIPMENT TYPE & MANUFACTURE 1998 Navy Design Bread Board
SERIAL NUMBER Prototype TEST DATE 8-26-98

APPLIED VOLTAGE	CIRCUIT OPEN <20 ms PASS	FAIL	COMMENTS
GFI output			Tested IAW NAVXDIVINGUINST 3960.3
B-W 111.5	✓		Fault resistance ajusted to simulate 10ma fault
~~W~~-G L1-GND 2.1	✓		
~~B~~-G L2-GND 112.8	✓		L1-GND fault: ~~21~~ 210 ohms
			L2-GND fault: 11.2k ohms

TEST EQUIPMENT USED:

TYPE	MANUFACTURE	SERIAL NO.	CAL. DATE
222	Tektronix O-scope	B017681	Aug 19, 2000
87	Fluke Multimeter	51201984	Nov 20, 1999

The above listed GFI was tested in accordance with NAVSEA provided procedure dated May 8, 1991 and NAVSEA instruction dated July 10, 1991.

Test Conducted By: [signature]

* NOTE: THE ABOVE LISTED GFI WAS MODIFIED AS REQUIRED BY NAVSEA 00C54, DATED 7-15-91.

04 Jan 1999

TO: D. S. GRAY
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the 1998 NAVY DESIGN BREADBOARD VERSION GFI Ground Fault Interrupter (GFI). After modifications to over current circuit. Conduct test in accordance with NAVXDIVINGU 3960.3.

2.0 Device under test:

NAVY DESIGN BREADBOARD (GFI)
Model: N/A
Ser.#: N/A

3.0 Test equipment:

1. GFI tester	NEDU in-house device	
2. Voltmeter	Fluke model 87	Cal due Nov. 20, 1999
3. Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFISETUP.DWG.
2. Power up system, connect ≈1500 watt resistive heater to GFI output.
3. Using the GFI tester induce a 210 ohm resistance to create a fault path between the L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.6 K ohm resistance to create a fault path between the L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test	Navy Design Breadboard	Results
L1 to Ground	Passed	5.96 ms (avg)
L2 to Ground	Passed	8.26 ms (avg)

Comments:

- GFI PASSED the test criteria
- Measured 2.1 volts between L1 (black) and ground
- Measured 116.4 volts between L2 (red) and ground
- Fault resistance = (voltage / .01 amps)

Larry Gene Gibbs Jr.
Test Technician

1998 Navy design breadboard GFI Reduced Data

Measured voltages at GFI output-

Not tripped	**No load Voltage**
L2 (red) - L1 (black)	115.3 volts
GND - L2	116.4 volts
GND - L1	2.11 volts

Tripped	**Voltage**	**Short Circuit Current**
L2 (red) - L1 (black)	98.0 mV	approx 1.3 microamps AC
GND - L2	55.5 volts	approx 233 microamps AC
GND - L1	55.5 volts	approx 234 microamps AC

L1 - GND fault-

Consistently triggered with faults less than 340 ohms.
Would not trigger with faults greater than 390 ohms.

L2 - GND fault-

Consistently triggered with faults less than 31K ohms.
Would not trigger with faults greater than 35K ohms.

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 210 ohm fault	L2 trigger time - 11.6k ohm fault
7.0 ms	4.6 ms
5.6 ms	11.6 ms
4.5 ms	7.7 ms
3.6 ms	7.9 ms
9.1 ms	9.5 ms
AVG	AVG
5.96 ms	8.26 ms

01 Mar 1999

TO: Jerry Pelton
VIA. Debbie Gray
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the 1998 NAVY DESIGN BREADBOARD VERSION GFI Ground Fault Interrupter (GFI). After modifications (Mod one) to over current circuit. And (mod two) output GND modification. Conducted test in accordance with NAVXDIVINGU 3960.3.

2.0 Device under test:

NAVY DESIGN BREADBOARD (GFI)
Model: ESSM-uw2310 (MOD 2 input/output GND isolation mod)
Ser.#: 007315

3.0 Test equipment:

1. GFI tester	NEDU in-house device	
2. Voltmeter	Fluke model 45	Cal due Aug. 15, 1999
3. Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFISETUP.DWG.
2. Add a 700-800 watt load to GFI output.
3. Using the GFI tester induce a 227 ohm resistance to create a fault path between the L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.8 K ohm resistance to create a fault path between the L2 and ground of the GFI output. Record GFI response time fault to power open.
4. Repeat steps 3 and 4 five times each.
5. Average the response times for steps 3 and 4.
6. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test	Navy Design Breadboard	Results
L1 to Ground	Passed	6.86 ms (avg)
L2 to Ground	Passed	6.64 ms (avg)

Comments:

- GFI PASSED the test criteria
- Measured 2.27 volts between L1 (black) and ground
- Measured 118.2 volts between L2 (red) and ground
- Fault resistance = (voltage / .01 amps)

Larry Gene Gibbs Jr
Test Technician

1998 Navy design breadboard GFI Reduced Data

Measured voltages at GFI output-

Not tripped	**No load Voltage**
L2 (red) - L1 (black)	115.9 volts
GND - L2	118.2 volts
GND - L1	2.27 volts

Tripped	**Voltage**	**Short Circuit Current**
L2 (red) - L1 (black) OUTPUT	2.04 mV	122.0 microamps AC
OUTPUTGND - OUTPUT L2	4.5 volts	15.00 microamps AC
OUTPUTGND - OUTPUT L1	4.5 volts	15.00 microamps AC
INPUT GND - OUTPUT L2	58.5volts	253 0 microamps AC
INPUT GND - OUTPUT L1	58.5 volts	253 0 microamps AC

L1 - GND fault-
Consistently triggered with faults less than 520 ohms.
Would not trigger with faults greater than 590 ohms.

L2 - GND fault-
Consistently triggered with faults less than 37K ohms.
Would not trigger with faults greater than 42K ohms.

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 227 ohm fault

5.3 ms
7.2 ms
6.2 ms
7.9 ms
7.7 ms

AVG
6.86 ms

L2 trigger time - 11.8k ohm fault

8.8 ms
6.9 ms
5.0 ms
3.9 ms
8.6 ms

AVG
6.64 ms

TO: D. S. GRAY 27 Oct 1999
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3.

2.0 Device under test:

manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0001

3.0 Test equipment:

1. GFI tester	NEDU in-house device	
2. Voltmeter	Beckman tech 360	Cal due Nov. 09, 2000
3. Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFISETUP.DWG.
2. Power up system, connect 1500 watt resistive load to GFI output.
3. Using the GFI tester induce a 306 ohm resistance to create a fault path between the L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.2 K ohm resistance to create a fault path between the L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test	Navy Design Breadboard	Results
L1 to Ground	Passed	6.52 ms (avg)
L2 to Ground	Passed	6.78 ms (avg)

Comments:

- GFI PASSED the test criteria
- Measured 3.06 volts between L1 (black) and ground
- Measured 112.7 volts between L2 (red) and ground
- Fault resistance = (voltage / .01 amps)

Larry Gene Gibbs Jr.
Test Technician

US NAVY 1.725 KVA 20 AMP (GFI) Reduced Data

Measured voltages at GFI output-

Not tripped (no load)	**Voltage**
L2 (red) - L1 (black)	111.4 volts
GND - L2	112.7 volts
GND - L1	3.06 volts

Tripped (no load)	**Voltage**	**Short Circuit Current**
L2 (red) - L1 (black)	39.2 mV	approx 29 microamps AC
GND - L2	11.4 volts	approx 249 microamps AC
GND - L1	11.4 volts	approx 247 microamps AC

L1 - GND fault-

Consistently triggered with faults less than 1.15K ohms.
Would not trigger with faults greater than 1.36K ohms.

L2 - GND fault-

Consistently triggered with faults less than 100K ohms.
Would not trigger with faults greater than 115K ohms.

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 306 ohm fault

6.7 ms
4.9 ms
6.2 ms
6.8 ms
8.0 ms

AVG
6.52 ms

L2 trigger time - 11.2k ohm fault

3.4 ms
10.3 ms
5.3 ms
10.8 ms
4.1 ms

AVG
6.78 ms

TO: D. S. GRAY

27 Oct 1999

From: Larry Gene Gibbs Jr.

Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3.

2.0 Device under test:

manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0002

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Beckman tech 360	Cal due Nov. 09, 2000
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFISETUP.DWG.
2. Power up system, connect 1500 watt resistive load to GFI output.
3. Using the GFI tester induce a 360 ohm resistance to create a fault path between the L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.3 K ohm resistance to create a fault path between the L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test	Navy Design Breadboard	Results
L1 to Ground	Passed	8.26 ms (avg)
L2 to Ground	Passed	5.14 ms (avg)

Comments:

- GFI PASSED the test criteria
- Measured 3.60 volts between L1 (black) and ground
- Measured 113.0 volts between L2 (red) and ground
- Fault resistance = (voltage / .01 amps)

Larry Gene Gibbs Jr.
Test Technician

US NAVY 1.725 KVA 20 AMP (GFI) Reduced Data

Measured voltages at GFI output-

Not tripped (no load)	**Voltage**
L2 (red) - L1 (black)	111.4 volts
GND - L2	113.0 volts
GND - L1	3.60 volts

Tripped (no load)	**Voltage**	**Short Circuit Current**
L2 (red) - L1 (black)	21.8 mV	approx 16.8 microamps AC
GND - L2	16.0 volts	approx 247 microamps AC
GND - L1	16.0 volts	approx 245 microamps AC

L1 - GND fault-
Consistently triggered with faults less than 510 ohms.
Would not trigger with faults greater than 560 ohms.

L2 - GND fault-
Consistently triggered with faults less than 38K ohms.
Would not trigger with faults greater than 45K ohms.

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 360 ohm fault

8.0 ms
4.9 ms
13.3 ms
10.5 ms
4.6 ms

AVG
8.26 ms

L2 trigger time - 11.3k ohm fault

5.6 ms
4.7 ms
3.6 ms
4.8 ms
7.0 ms

AVG
5.14 ms

15 NOV 1999

TO: D. S. GRAY
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (After increased temperature testing))

2.0 Device under test:

manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0001

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Beckman tech 360	Cal due Nov. 09, 2000
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFISETUP.DWG.
2. Power up system, connect 750 watt resistive load to GFI output.
3. Using the GFI tester induce a 306 ohm resistance to create a fault path between the L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.2 K ohm resistance to create a fault path between the L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test	Navy Design Breadboard	Results
L1 to Ground	Passed	6.90 ms (avg)
L2 to Ground	Passed	5.40 ms (avg)

Comments:

- GFI PASSED the test criteria
- Measured 3.06 volts between L1 (black) and ground
- Measured 112.7 volts between L2 (red) and ground
- Fault resistance = (voltage / .01 amps)

Larry Gene Gibbs Jr
Test Technician

US NAVY 1.725 KVA 20 AMP (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 306 ohm fault

5.4 ms
12.1 ms
3.8 ms
7.0 ms
6.2 ms

AVG
6.90 ms

L2 trigger time - 11.2k ohm fault

9.3 ms
8.4 ms
3.0 ms
2.7 ms
3.6 ms

AVG
5.40 ms

TO: D. S. GRAY 15 Nov 1999
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (After increased temperature testing)

2.0 Device under test:

manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0002

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Beckman tech 360	Cal due Nov. 09, 2000
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFISETUP.DWG.
2. Power up system, connect 750 watt resistive load to GFI output.
3. Using the GFI tester induce a 360 ohm resistance to create a fault path between the L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.3 K ohm resistance to create a fault path between the L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test	Navy Design Breadboard	Results
L1 to Ground	Passed	12.42 ms (avg)
L2 to Ground	Passed	6.62 ms (avg)

Comments:

- GFI PASSED the test criteria
- Measured 3.60 volts between L1 (black) and ground
- Measured 113.0 volts between L2 (red) and ground
- Fault resistance = (voltage / .01 amps)

Larry Gene Gibbs Jr.
Test Technician

US NAVY 1.725 KVA 20 AMP (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 360 ohm fault

13.2 ms
8.1 ms
15.2 ms
15.3 ms
10.4 ms

AVG
12.42 ms

L2 trigger time - 11.3k ohm fault

4.7 ms
8.8 ms
3.9 ms
8.6 ms
7.1 ms

AVG
6.62 ms

TO: D. S. GRAY 1 MAR 2000
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:
Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP REV 2 (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (REV 2, modified power plugs)(Before rain shower testing)

2.0 Device under test:
manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0002

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Fluke 45	Cal due Aug. 15, 2000
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:
1. Assemble test setup as shown in drawing GFISETUP.DWG.
2. Power up system.
3. Using the GFI tester induce a 570 ohm resistance to create a fault path between the L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.28 K ohm resistance to create a fault path between the L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test		Results
L1 to Ground	Passed	13.58 ms (avg)
L2 to Ground	Passed	6.92 ms (avg)

Larry Gene Gibbs
Test Technician

US NAVY 1.725 KVA 20 AMP (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 570 ohm fault

21.00 ms
7.00 ms
11.00 ms
13.30 ms
15.60 ms

AVG
13.58 ms

L2 trigger time - 11.28k ohm fault

10.90ms
7.70 ms
5.00 ms
5.10 ms
5.90 ms

AVG
6.92 ms

1 MAR 2000

TO: D. S. GRAY
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP REV 2 (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (REV 2, modified power plugs)(Before rain shower testing)

2.0 Device under test:

manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0001

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Fluke 45	Cal due Aug. 15, 2000
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFISETUP.DWG.
2. Power up system.
3. Using the GFI tester induce a 283 ohm resistance to create a fault path between the L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.26 K ohm resistance to create a fault path between the L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test		Results
L1 to Ground	Passed	5.54 ms (avg)
L2 to Ground	Passed	6.24 ms (avg)

Test Technician

US NAVY 1.725 KVA (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :

(voltage to ground / .01 amps)

L1 trigger time - 283 ohm fault

4.3 ms
4.0 ms
10.7 ms
4.5 ms
4.2 ms

AVG
5.54 ms

L2 trigger time - 11.26k ohm fault

6.6 ms
4.1 ms
7.9 ms
9.9 ms
2.7 ms

AVG
6.24 ms

GROUND FAULT INTERRUPTER (GFI)
TEST DATA REPORT

Equipment Type & Manufacture:
US Navy 1.75 KVA GFI
Serial Number: 0001 Test Date MAR. 1,2000

GFI AC VOLTAGE LEGS	INTO	OUT OF	CIRCUIT OPEN < 20ms Pass	Fail	COMMENTS
L1-L2		111.6	*		TEST IAW NAVXDIVINGUINST3960.3
L1-G		2.83	*		FAULT RESISTANCE AJUSTED TO
L2-G		112.6	*		SIMULATE A 10ma FAULT.
					L1 to GND fault = 283 ohms
					L1 to GND fault = 11.26K ohms

TEST EQUIPMENT USED:

TYPE	MANUFACTURE	SERIAL NO.	*CAL. DUE DATE*
Scope	Tektronix 222	B017681	*AUG. 19, 2000*
VOM	fluke 45	5040342	*AUG. 15, 2000*

TEST CONDUCTED BY : 

16 MAR 2000

TO: D. S. GRAY
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP REV 2 (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (REV 2, modified power plugs)(After rain shower testing)

2.0 Device under test:

manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0001

3.0 Test equipment:

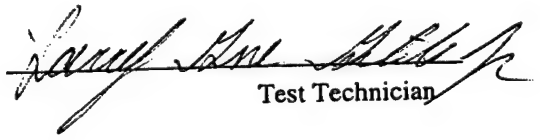
1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Fluke 87	Cal due 2002 day 120
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFI SETUP.DWG.
2. Power up system, load GFI with approximately 500 watts of resistive load.
3. Using the GFI tester induce a 273 ohm resistance to create a fault path between the L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.23 K ohm resistance to create a fault path between the L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test		Results
L1 to Ground	Passed	9.30 ms (avg)
L2 to Ground	Passed	5.12 ms (avg)



Test Technician

US NAVY 1.725 KVA (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :

(voltage to ground / .01 amps)

L1 trigger time - 273 ohm fault

8.3 ms
10.2 ms
11.9 ms
5.7 ms
10.4 ms

AVG
9.3 ms

L2 trigger time - 11.23k ohm fault

5.1 ms
5.2 ms
4.4 ms
3.4 ms
7.5 ms

AVG
5.12 ms

16 MAR 2000

TO: D. S. GRAY
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:
Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP REV 2 (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (REV 2, modified power plugs)(after rain shower testing)

2.0 Device under test:
manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0002

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Fluke 87	Cal due 2002 day 120
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:
1. Assemble test setup as shown in drawing GFI SETUP.DWG.
2. Power up system, load GFI with approximately 500 watts of resistive load.
3. Using the GFI tester induce a 228 ohm resistance to create a fault path between the L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.30 K ohm resistance to create a fault path between the L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test		Results
L1 to Ground	Passed	5.84 ms (avg)
L2 to Ground	Passed	7.16 ms (avg)

Larry Gene Gibbs Jr
Test Technician

US NAVY 1.725 KVA 20 AMP (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 228 ohm fault	L2 trigger time - 11.30k ohm fault
9.50 ms	6.60 ms
3.50 ms	9.20 ms
7.70 ms	10.00 ms
3.40 ms	2.50 ms
5.10 ms	7.50 ms
AVG	AVG
5.84 ms	7.16 ms

TO: D. S. GRAY

21 MARCH 2000

From: Larry Gene Gibbs Jr.

Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP REV 2 (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (REV 2, modified power plugs)(after OP cold test)

2.0 Device under test:

manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0002

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Fluke 87	Cal due 2002 day 120
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFI SETUP.DWG.
2. Power up system, load GFI with approximately 300 watts of resistive load.
3. Using the GFI tester induce a 232 ohm resistance to create a fault path between L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.55 K ohm resistance to create a fault path between L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test		Results
L1 to Ground	Passed	5.04 ms (avg)
L2 to Ground	Passed	8.22 ms (avg)

Larry Gene Gibbs Jr.
Test Technician

US NAVY 1.725 KVA 20 AMP (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 232 ohm fault	L2 trigger time - 11.55k ohm fault
7.20 ms	7.00 ms
8.90 ms	8.70 ms
3.80 ms	9.70 ms
2.50 ms	6.50 ms
2.80 ms	9.20 ms
AVG	AVG
5.04 ms	8.22 ms

TO: D. S. GRAY

21 MARCH 2000

From: Larry Gene Gibbs Jr.

Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP REV 2 (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (REV 2, modified power plugs)(After op cold test)

2.0 Device under test:

manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0001

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Fluke 87	Cal due 2002 day 120
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFI SETUP.DWG.
2. Power up system, load GFI with approximately 300 watts of resistive load.
3. Using the GFI tester induce a 267 ohm resistance to create a fault path between L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.20 K ohm resistance to create a fault path between L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test		Results
L1 to Ground	Passed	6.74 ms (avg)
L2 to Ground	Passed	6.40 ms (avg)

Larry Gene Gibbs Jr

Test Technician

US NAVY 1.725 KVA (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :

(voltage to ground / .01 amps)

L1 trigger time - 267 ohm fault

4.80 ms
5.40 ms
5.70 ms
12.1 ms
5.70 ms

AVG
6.74 ms

L2 trigger time - 11.20K ohm fault

6.80 ms
4.70 ms
3.80 ms
5.60 ms
11.1 ms

AVG
6.40 ms

24 MARCH 2000

TO: D. S. GRAY
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP REV 2 (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (REV 2, modified power plugs)(After 118°F testing)

2.0 Device under test:

manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0001

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Fluke 87	Cal due 2002 day 120
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFI SETUP.DWG.
2. Power up system, load GFI with approximately 300 watts of resistive load.
3. Using the GFI tester induce a 273 ohm resistance to create a fault path between L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.26 K ohm resistance to create a fault path between L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test		Results
L1 to Ground	Passed	9.08 ms (avg)
L2 to Ground	Passed	6.08 ms (avg)

Larry Gene Gibbs Jr
Test Technician

US NAVY 1.725 KVA (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :

(voltage to ground / .01 amps)

L1 trigger time - 273 ohm fault

11.7 ms
4.70 ms
7.60 ms
12.1 ms
9.30 ms

AVG
9.08 ms

L2 trigger time - 11.26K ohm fault

2.40 ms
2.70 ms
9.80 ms
5.90ms
9.60 ms

AVG
6.08 ms

TO: D. S. GRAY

24 MARCH 2000

From: Larry Gene Gibbs Jr.

Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP REV 2 (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (REV 2, modified power plugs)(after 118°F testing)

2.0 Device under test:

manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0002

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Fluke 87	Cal due 2002 day 120
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFI SETUP.DWG.
2. Power up system, load GFI with approximately 300 watts of resistive load.
3. Using the GFI tester induce a 215 ohm resistance to create a fault path between L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.15 K ohm resistance to create a fault path between L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test		Results
L1 to Ground	Passed	7.95 ms (avg)
L2 to Ground	Passed	6.26 ms (avg)

Larry Gene Gibbs Jr.
Test Technician

US NAVY 1.725 KVA 20 AMP (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 215 ohm fault

4.80 ms
ms
9.50 ms
8.40 ms
9.10 ms

AVG (of 4)
7.95 ms

L2 trigger time - 11.15k ohm fault

5.10 ms
2.50 ms
10.0 ms
8.60 ms
5.10 ms

AVG
6.26 ms

10 APR 2000

TO: D. S. GRAY
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP REV 2 (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (REV 2, modified power plugs)(After vibration testing)

2.0 Device under test:

manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0001

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Fluke 87	Cal due 2002 day 120
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFI SETUP.DWG.
2. Power up system, load GFI with approximately 300 watts of resistive load.
3. Using the GFI tester induce a 260 ohm resistance to create a fault path between L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.34 K ohm resistance to create a fault path between L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test		Results
L1 to Ground	Passed	6.98 ms (avg)
L2 to Ground	Passed	6.64 ms (avg)

Test Technician

US NAVY 1.725 KVA (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :

(voltage to ground / .01 amps)

L1 trigger time - 260 ohm fault

3.9 ms
6.1 ms
4.5 ms
10.7 ms
9.7 ms

AVG
6.98 ms

L2 trigger time - 11.34K ohm fault

4.4 ms
8.7 ms
10.9ms
5.1 ms
4.1 ms

AVG
6.64 ms

TO: D. S. GRAY 10 APR 2000
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:
Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP REV 2 (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (REV 2, modified power plugs)(after vibration testing)

2.0 Device under test:
manufacture: GPC
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Ser.#: main board # 0002

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Fluke 87	Cal due 2002 day 120
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:
1. Assemble test setup as shown in drawing GFI SETUP.DWG.
2. Power up system, load GFI with approximately 300 watts of resistive load.
3. Using the GFI tester induce a 264 ohm resistance to create a fault path between L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 11.36 K ohm resistance to create a fault path between L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test		Results
L1 to Ground	Passed	6.62 ms (avg)
L2 to Ground	Passed	5.10 ms (avg)

Larry Gene Gibbs Jr
Test Technician

US NAVY 1.725 KVA 20 AMP (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 264 ohm fault

8.80 ms
6.30 ms
7.10 ms
6.40 ms
4.50 ms

AVG
6.62 ms

L2 trigger time - 11.36k ohm fault

2.50 ms
3.60 ms
7.40 ms
5.60 ms
6.40 ms

AVG
5.10 ms

TO: D. S. GRAY 12 APR 2000
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:

Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP REV 2 (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (REV 2, modified power plugs)(After drop testing)

2.0 Device under test:

manufacture: GPC
Model: US NAVY 1.725 KVA 20 AMP GFI Assembly
Ser.#: main board # 0001

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Fluke 87	Cal due 2002 day 120
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:

1. Assemble test setup as shown in drawing GFI SETUP.DWG.
2. Power up system, load GFI with approximately 800 watts of resistive load.
3. Using the GFI tester induce a 266 ohm resistance to create a fault path between L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 10.6 K ohm resistance to create a fault path between L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test		Results
L1 to Ground	Passed	5.28 ms (avg)
L2 to Ground	Passed	7.46 ms (avg)

Larry Gene Gibbs Jr.
Test Technician

US NAVY 1.725 KVA (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :

(voltage to ground / .01 amps)

L1 trigger time - 266 ohm fault

5.1 ms
6.5 ms
4.3 ms
4.2 ms
6.3 ms

AVG
5.28 ms

L2 trigger time - 10.6K ohm fault

5.0 ms
4.2 ms
7.4 ms
11.1 ms
9.6 ms

AVG
7.46 ms

TO: D. S. GRAY 12 APR 2000
From: Larry Gene Gibbs Jr.
Subj: Ground Fault Interrupter Evaluation

1.0 Objective:
Determine the operating parameters of the US NAVY 1.725 KVA 20 AMP REV 2 (GFI) Ground Fault Interrupter. Conduct test in accordance with NAVXDIVINGU 3960.3. (REV 2, modified power plugs)(after drop testing)

2.0 Device under test:
manufacture: GPC
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Ser.#: main board # 0002

3.0 Test equipment:

1.	GFI tester	NEDU in-house device	
2.	Voltmeter	Fluke 87	Cal due 2002 day 120
3.	Oscilloscope	Tektronix model 222	Cal due Aug. 19, 2000

4.0 Test procedure:
1. Assemble test setup as shown in drawing GFI SETUP.DWG.
2. Power up system, load GFI with approximately 800 watts of resistive load.
3. Using the GFI tester induce a 253 ohm resistance to create a fault path between L1 and ground of the GFI output. Record GFI response time fault to power open.
4. Using the GFI tester induce a 10.7 K ohm resistance to create a fault path between L2 and ground of the GFI output. Record GFI response time fault to power open.
5. Repeat steps 3 and 4 five times each.
6. Average the response times for steps 3 and 4.
7. If the average response is greater than 20ms., the unit fails the test criteria.

5.0 Test results:

Test		Results
L1 to Ground	Passed	5.96 ms (avg)
L2 to Ground	Passed	5.18 ms (avg)

Larry Gene Gibbs Jr.
Test Technician

US NAVY 1.725 KVA 20 AMP (GFI) Reduced Data

Faults used for timing measurements are based on the following equation :
(voltage to ground / .01 amps)

L1 trigger time - 253 ohm fault	L2 trigger time - 10.7k ohm fault
6.80 ms	4.10 ms
4.0 ms	2.60 ms
6.40 ms	6.60 ms
3.60 ms	7.90 ms
9.00 ms	4.70 ms
AVG	AVG
5.96 ms	5.18 ms

DAHLGREN DIVISION
NAVAL SURFACE WARFARE CENTER
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ELPR – 2000 – 02

Environmental Testing of a Portable Electrical Ground Fault Interrupt Unit

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18 MAY 2000

ENCLOSURE (2)

Results Of Environmental Testing Of
A
Portable Electrical Ground Fault Interrupt (GFI) Unit

1.0 Background

Coastal Systems Station, Code E21, was requested by the Navy Experimental Diving Unit (NEDU) to perform environmental testing on a portable Electrical Ground Fault Interrupt (GFI) Unit. This unit is currently under development by NAVSEA, and the environmental tests were developed to qualify the unit for use aboard ship.

The environmental testing was performed in two test series. The first series was started in November, 1999. Due to failures during the testing, the first test series was aborted in December, 1999. The units were returned to the manufacturer for repair and design change and returned to CSS in February, 2000. The second test series was performed starting in March, 2000 with completion in April, 2000. This report provides the results of all of the environmental tests performed.

2.0 Description of Equipment

The GFI unit provides a ground fault circuit when using portable electric equipment aboard ships. The unit can be plugged into any 110 Volt, single phase receptacle and provides a total of four 110V output receptacles. The unit has a test switch which can test the GFI circuitry by providing a "trip" condition for both the "low" and "high" sides of the receptacles. In addition, a reset switch is provided to reset the unit after the test is performed or if the unit experiences a ground fault condition. There are also LED's which provide indications as to the current state of the unit. A total of four units were tested.

Two units were tested in the initial test program these units were configured as delivered from the manufacturer. As a result of the initial test series, the units were redesigned and the initial units were refurbished with the new design changes. The refurbished units were used in a follow-on test series. The most significant change was the receptacles were replaced with a more "watertight" version. In addition, some connector retaining clamps were added to the PC board.

3.0 Functional Performance

Prior to any environmental testing being performed, operational performance was verified by NEDU. In addition, before and after each environmental exposure, a measurement of the delay time for the circuit to "trip" was made as a means of assessing performance. The results of these tests are included as a separate report provided by NEDU. For some of the operational tests, during the environmental exposure, a quick

measure of performance was made by toggling the "test" switch; verifying that the power was removed to the receptacles; "resetting" the unit; and verifying that the power was restored. This test was performed by Code E31 personnel, as needed, throughout the testing program.

4.0 Testing Program

Prior to the start of the testing, a review of the environmental requirements was performed and test recommendations were made. Based on these recommendations and requirements, a series of tests were developed that would adequately determine the performance and survivability characteristics of each unit. It was determined that the following tests would be performed:

High Temperature Operation
Low Temperature Operation
Vibration
Rain
Low Temperature Storage and Transit Drops

A test plan was developed to serve as a guide for performing the tests and is included as Appendix A. The test plan also provides a detailed description of each test performed, with the specific environmental conditions for each. Where applicable, the tests followed the recommendations made in MIL-STD-810E. For the first test series the test program was performed in the order as listed above. However, the Low Temperature Drops were not performed due to excessive water intrusion during the Rain Test.

For the second series, since the units previously had the most problems with the Rain Test, it was decided to perform the Rain Test first. Additionally, due to personnel scheduling, it became more cost and time effective to perform the Low Temperature Operation test before the High Temperature test. Therefore the order of testing for the second test series was as follows:

Rain
Low Temperature Operation
High Temperature Operation
Vibration
Low Temperature Storage and Transit Drops

5.0 Test Results

5.1 Test Series One

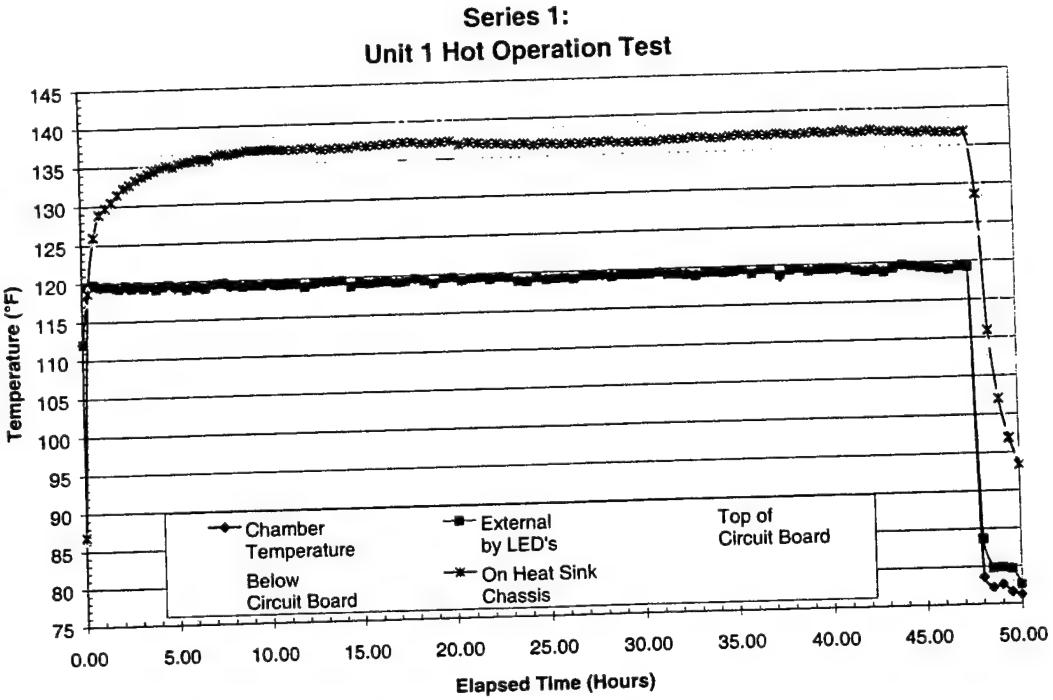
5.1.1 High Temperature Operation

The two units were placed into a temperature chamber and instrumented with thermocouples. Each unit had thermocouples located as follows: external near the LED and switch panel; on top of the circuit board; under the circuit board, over the coil; and on the SCR chassis. In addition, one thermocouple was placed in the air, between the two units. For equipment monitoring during the test, a small electric analog clock was plugged into each unit. This provided a small load that could determine the operational state of each and could determine, if necessary, the approximate time of failure between operational readings.

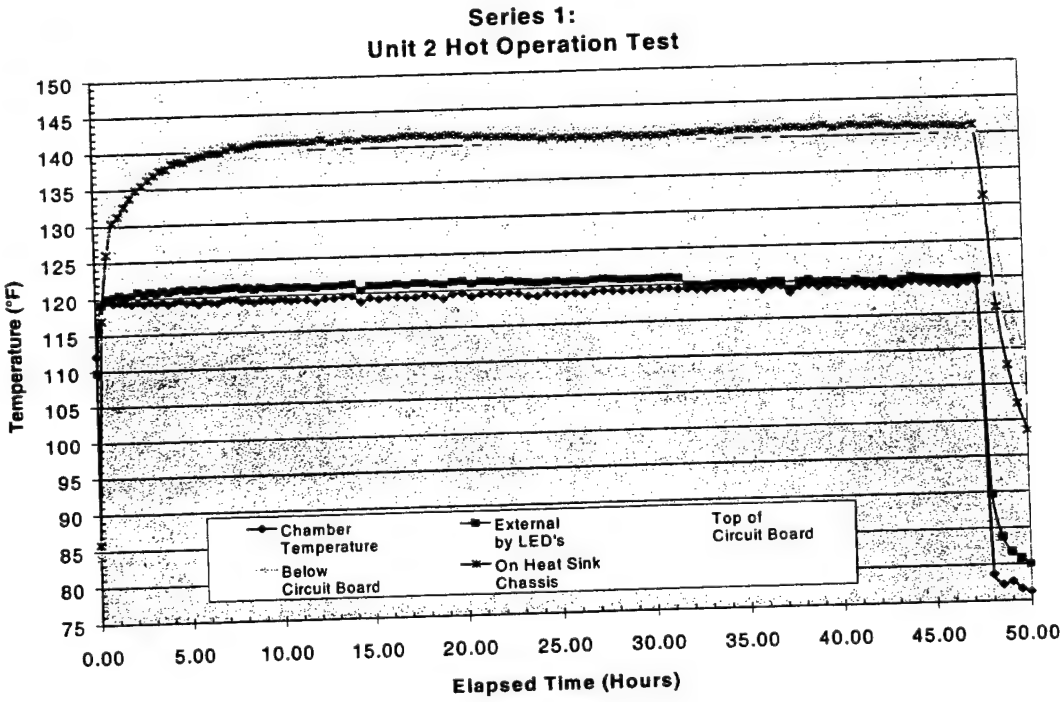
The testing was begun on November 4, 1999. The units were preconditioned to 119 °F and maintained for approximately 2 hours prior to starting the test. Once the unit was preconditioned, the operational test was started by manually toggling the "TEST" switch alternately between the "LOW" and "HIGH" positions. The "RESET" switch was manually depressed to reset the unit. This test was repeated approximately once each hour throughout the testing.

Approximately 3 hours into the testing, both units quit operating. The testing was immediately aborted and the units were returned to NEDU for evaluation. It was determined that an internal fuse had blown in each unit. The fuse was replaced with a higher current fuse and the units were returned for testing.

The testing was resumed on November 9, 1999. Since the failure occurred so early in the test, it was decided that the test should be performed for the full 48 hours. However, the 2 hour soak was eliminated and the test was started as soon as the units were placed in the chamber. The testing was completed on November 11, 1999 with no anomalies observed. Figure 1 shows the temperature profile for each unit over the course of the test. This data indicates that Unit 2 had a slightly higher average internal temperature than Unit 1. The appropriate test data sheets and operational log is included in Appendix B. At the completion of the test, NEDU personnel performed the appropriate functional tests and found the units to be operating correctly.



(a)



(b)

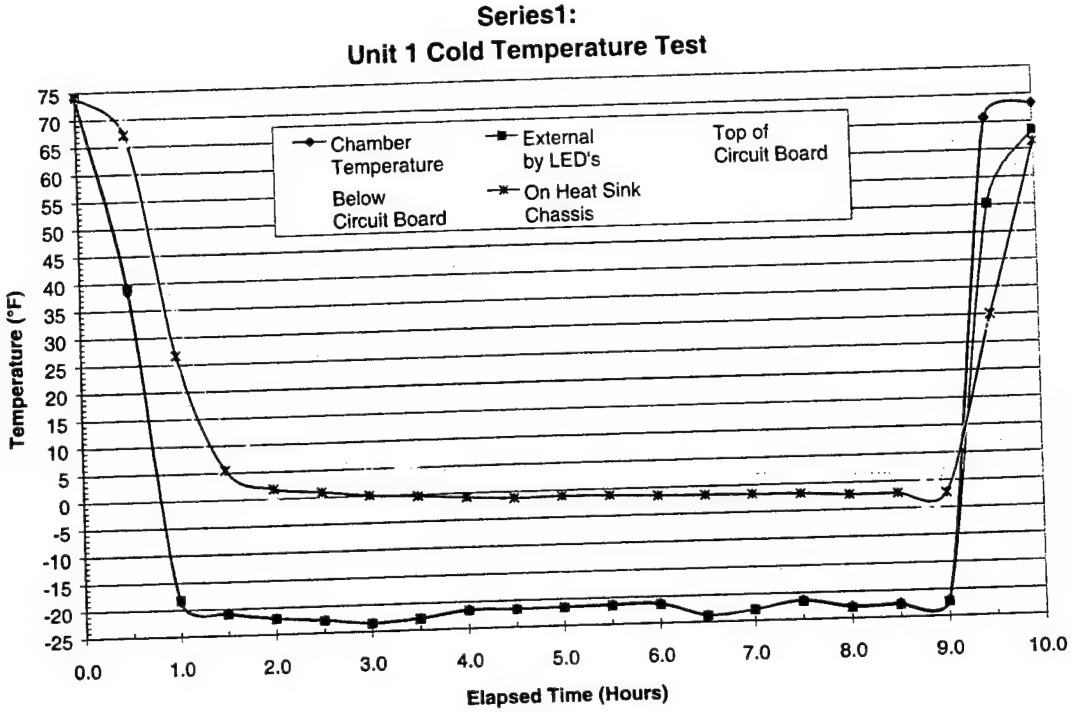
FIGURE 1: Temperature Profiles During Hot Operation Testing of the GFI Units (a) Unit 1 (b) Unit 2

5.1.2 Low Temperature Operation

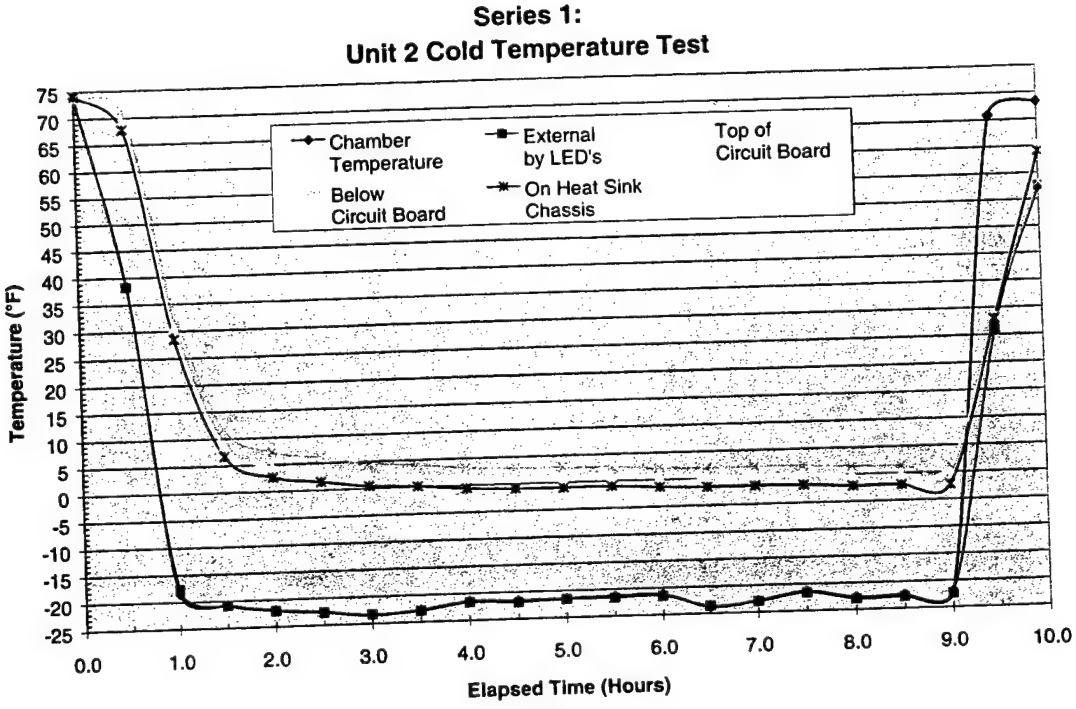
As with the High Temperature Operation Test, the units were placed into the temperature chamber and instrumented with thermocouples. The sensor locations were identical to the previous test. The analog clocks were also used to assess functionality.

The testing was begun on November 19, 1999. The units were preconditioned for approximately 2 hours prior to test start. The operational test was performed the same as for the High Temperature Operation. This test was performed for a total of 8 hours. Figure 2 shows the temperature profile for each unit during this test.

The testing was completed with only one minor anomaly. The trip LOW switch for Unit 1 did not always function. Throughout the test it would require toggling the switch 3 or 4 times in order to activate the unit. Once activated, the unit would reset correctly and continued to operate normally. This anomaly was not observed in Unit 2. At the completion of the test the switch returned to normal operation. No other anomalies were observed. At the completion of the test, NEDU personnel performed the appropriate functional tests and found the units to be operating correctly.



(a)



(b)

FIGURE 2: Temperature Profiles During Cold Operation Testing of the GFI Units
(a) Unit 1 (b) Unit 2

5.1.3 Vibration

The vibration test was performed on each unit separately in three mutually perpendicular directions. The three directions chosen were defined as follows: (1) Vertical – perpendicular to the face or LED panel, (2) Longitudinal – perpendicular to the GFI handles, and (3) Transverse – perpendicular to the receptacles. Figure 3 shows one unit ready for testing in the vertical direction. The unit was mounted similarly to the vibration table for testing in the other two directions.

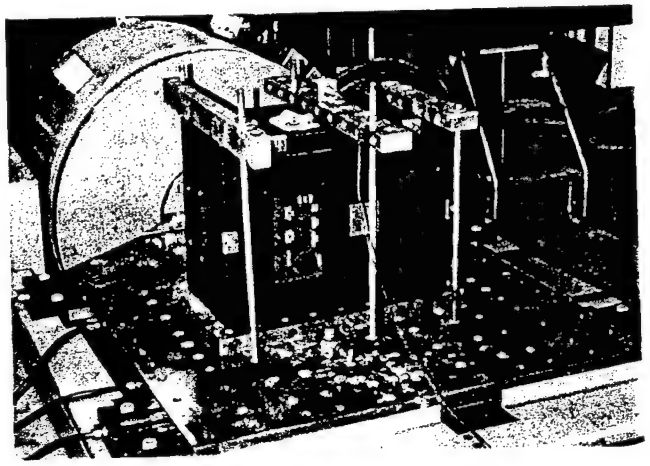


FIGURE 3: GFI Mounted to vibration table for testing in the Vertical Direction

The test was performed using the levels recommended by MIL-STD-810E, Method 514.4, Category 1, Basic Transportation. The recommended test profiles for the vertical and longitudinal directions were used for testing. The recommended transverse profile was not used. Since the orientation of the unit in the X-Y plane is arbitrary during shipment and operation, it was decided to use the test profile which provided the higher overall grms level for testing in the X-Y plane. Therefore the test profile as defined by Figure 514.4-3 in MIL-STD-810E (Longitudinal) was used for both the longitudinal and transverse directions. The test profile as defined by MIL-STD-810E, Figure 514.4-1 (Vertical) was used for the vertical direction.

Two accelerometers were used for control of the test. One accelerometer was located on the vibration table and one accelerometer was located on top of one of the tie down bars. The accelerometer locations for the vertical direction can be seen in Figure 2. Figure 4 shows the typical responses observed for testing in all three directions. For all plots the center trace is the average of the two accelerometers. The blue (upper) trace is the accelerometer on the table and the green (lower) is on the top of the fixture.

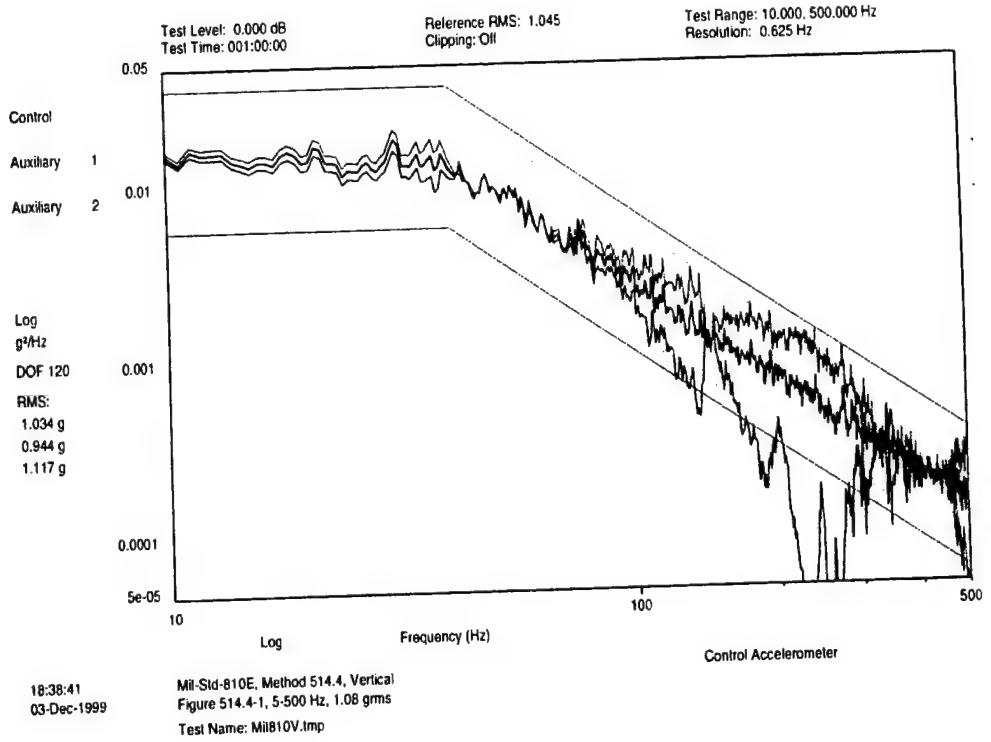


FIGURE 4A: Typical vibration test profiles showing difference between the two control accelerometers for the Vertical Direction

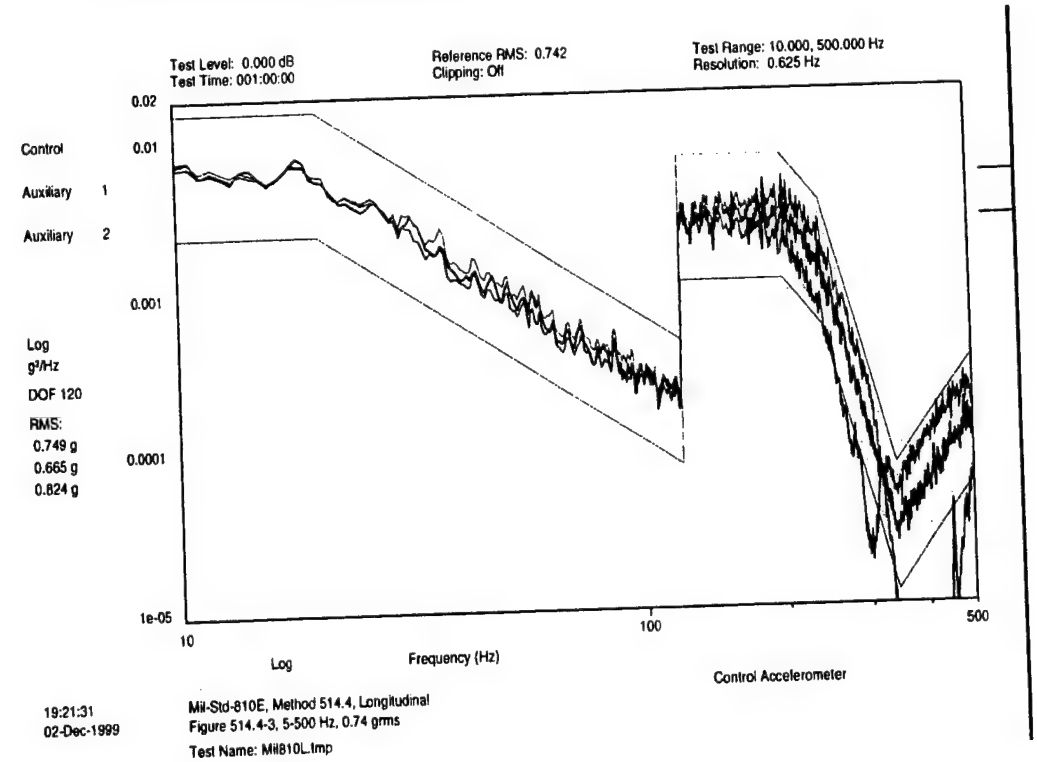


FIGURE 4B: Typical vibration test profiles showing difference between the two control accelerometers for the Longitudinal Direction

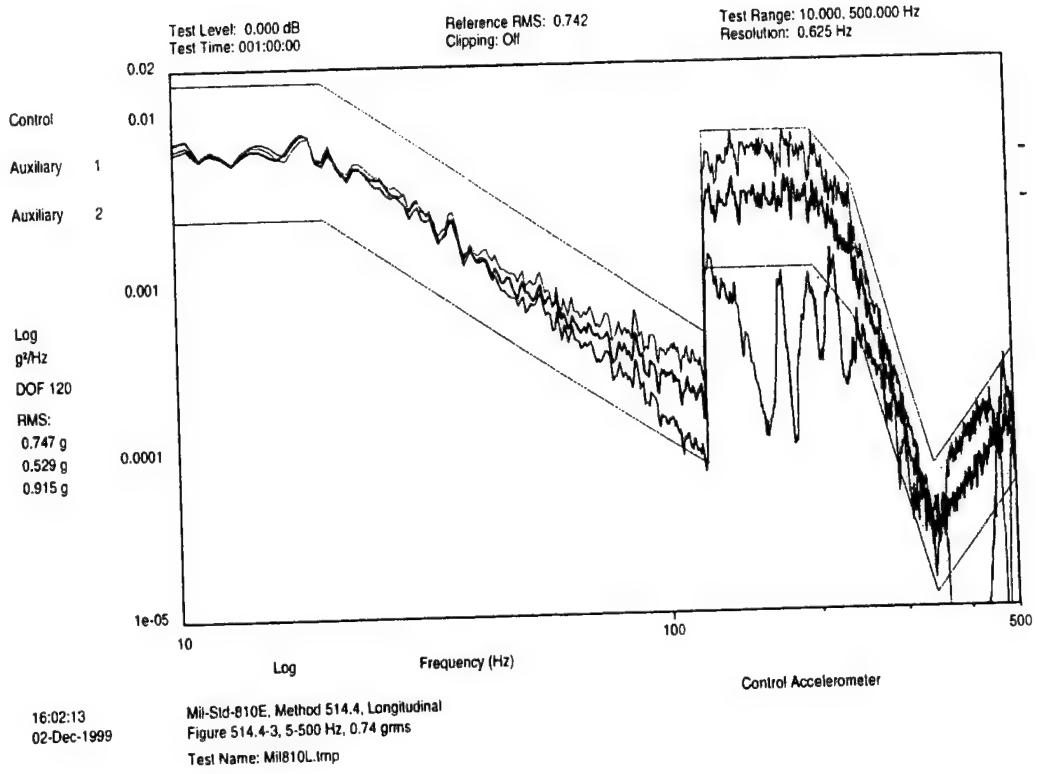


FIGURE 4C: Typical vibration test profiles showing difference between the two control accelerometers for the Transverse Direction

The vibration test was performed with the unit in the non-operational state. Unit 1 was tested in all three directions and then was functionally tested. When the unit was plugged in, the unit did not operate correctly. The unit was opened it was discovered that two of the connectors were disconnected from the circuit board. Figure 5 shows the loosened connectors. These connectors were reconnected and the unit returned to normal operation. Unit 2 was tested in two directions (transverse and longitudinal) and then was visually examined. This unit also had loose connectors. They were reconnected and the unit operated normally. The third direction (Vertical) was tested, and again the connectors loosened. They were again reconnected and the unit functioned normally. At the completion of the vibration testing, the units were tested by NEDU personnel. The units were found to be functioning properly.

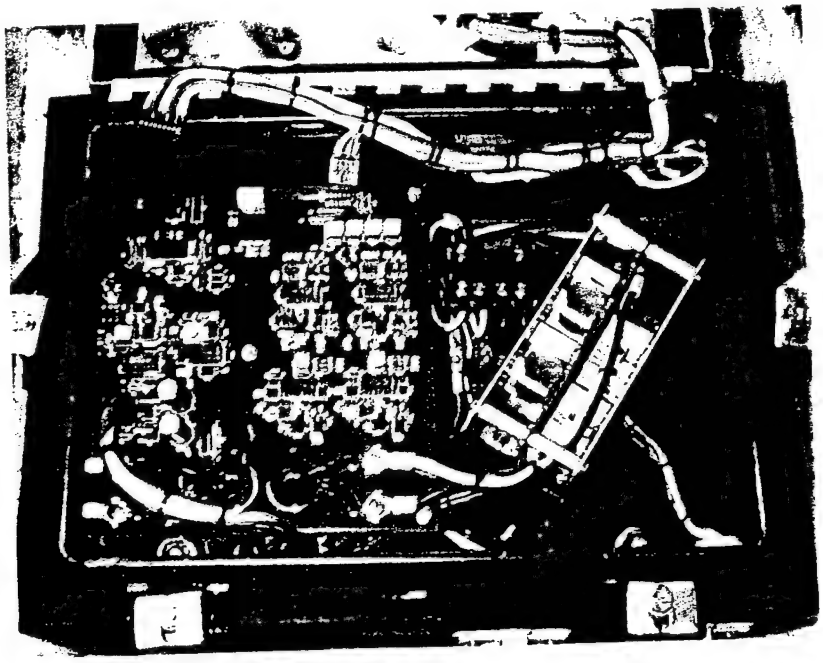
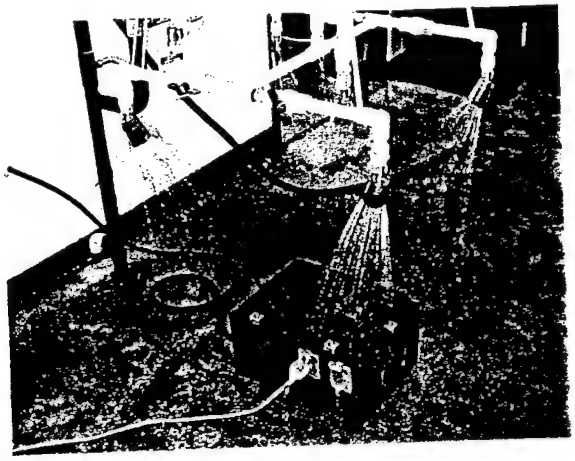


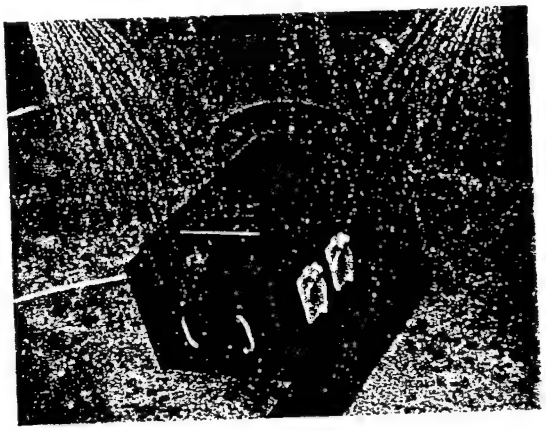
FIGURE 5: Loosened Connectors at the Completion of the Vibration Test

5.1.4 Rain

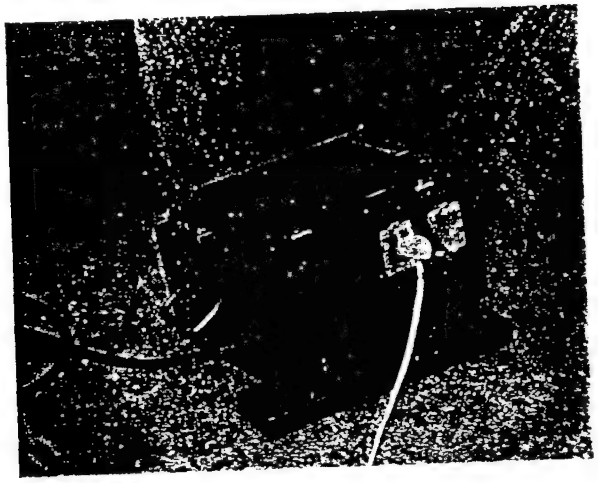
The rain test was performed on each unit separately. Unit 1 was subjected to a total of 120 minutes of testing in 3 orientations. In the first orientation, the spray was predominantly projected onto the top surface of the unit. In the second orientation, the spray was directed towards the outlets on one side. The third orientation, the spray was directed towards the outlets on the opposite side and where the power cable penetrated the housing. Figure 6 shows the three orientations of the unit during the rain test.



(a)



(b)



(c)

FIGURE 6: Orientation of Unit During the Rain Test
(a) Orientation 1, on top with spay nozzle arrangement
(b) Orientation 2, on receptacles without device plugged in
(c) Orientation 3, on receptacles and cord penetration with device plugged in

During the rain test, at approximately 20 minute intervals, the unit was functionally tested. The unit was "tripped" and reset for both the "high" and "low" conditions. The unit performed as expected throughout the test. At the completion of rain testing in all orientations, the unit was opened to determine the amount of water intrusion. Upon opening it was discovered that the bottom of the unit was completely covered with water, to a depth of approximately ¼ inch.

Because of the amount of water intrusion observed by the first unit, the second unit was only run in one orientation. The orientation chosen was considered the "worst case" condition. The water was aimed predominately at the side with the load plugged in. At the end of 40 minutes the test was stopped and the unit was opened and examined. There was approximately 1/8 inch of water covering the bottom. However, it was discovered that the mounting screws on the receptacles were slightly loose. These screws were tightened and the unit was dried. The test was then repeated for the same orientation. Again the unit had water inside.

Since both units had water intrusion, it was decided to abort the testing at this time. The units were returned to NEDU for repair and changes.

5.2 Series Two

5.2.1 Rain

The Series Two Rain Test was begun on March 7, 2000. The first unit was exposed to 40 minutes of rain in each of 4 different orientations. The first three orientations were similar to those used in the first test series: predominately on top and on each side with receptacles. The fourth direction was on the side where the input power cord penetrates the case. At the completion of the test, the first unit was opened and approximately 1-2 ounces of water was inside.

The second unit was tested on March 8, 2000. Testing was completed for the first orientation: on the top. However during testing in the second direction, the unit failed to reset. The unit was opened to assess the problem. Upon opening it was discovered that there was approximately 2-3 ounces of water inside. In addition it was discovered that the internal, ¼ amp fuse was blown. This fast-blow fuse was replaced with a ¼ amp slow-blow fuse. The unit was dried and was found to be operational

Since both units had water intrusion, it was decided to determine the cause for the intrusion as well as test potential solutions. Unit one was tested in one orientation with all the receptacles closed off (nothing plugged in). At the completion of the 40 minutes, the unit was opened and found to be dry. The test was repeated with a load plugged in which had a shroud over the wire. Upon completion of 40 minutes of testing, the unit was opened. There was approximately 2-3 ounces of water inside. Therefore it became apparent that the water was coming through the receptacle penetrations.

It was decided to replace some of the receptacles with a watertight receptacle which requires a specific mating plug. The receptacle used was manufactured by Daniel Woodhead Co., P/N 60W47. Unit 1 was retrofitted with one of these watertight receptacles and Unit 2 was retrofitted with two, one on each side. Once the installation was complete, the units were ready for retesting.

Unit 1 was setup for the rain test while having a load plugged into the new outlet. The test was started on March 10, 2000. Two orientations (on top and on side with load plugged in) were completed with no visible signs of water intrusion. The test was attempted for Unit 2. However, prior to starting the test, the unit was found to be non-functional. Investigation into the problem revealed a bad capacitor (C24). This was replaced and the unit was again functional. On March 15, the Rain test was completed for unit 2 in two orientations with no visible signs of water intrusion.

Discussions with the equipment manufacturer indicated that the receptacles that were initially installed (with screw cap), were designed to be used with a "booted" plug. One of the boots was obtained from the manufacturer and was installed onto the load plug. On March 15, 2000, the rain test was repeated for Unit 1 in one orientation. No visible signs of water intrusion were observed.

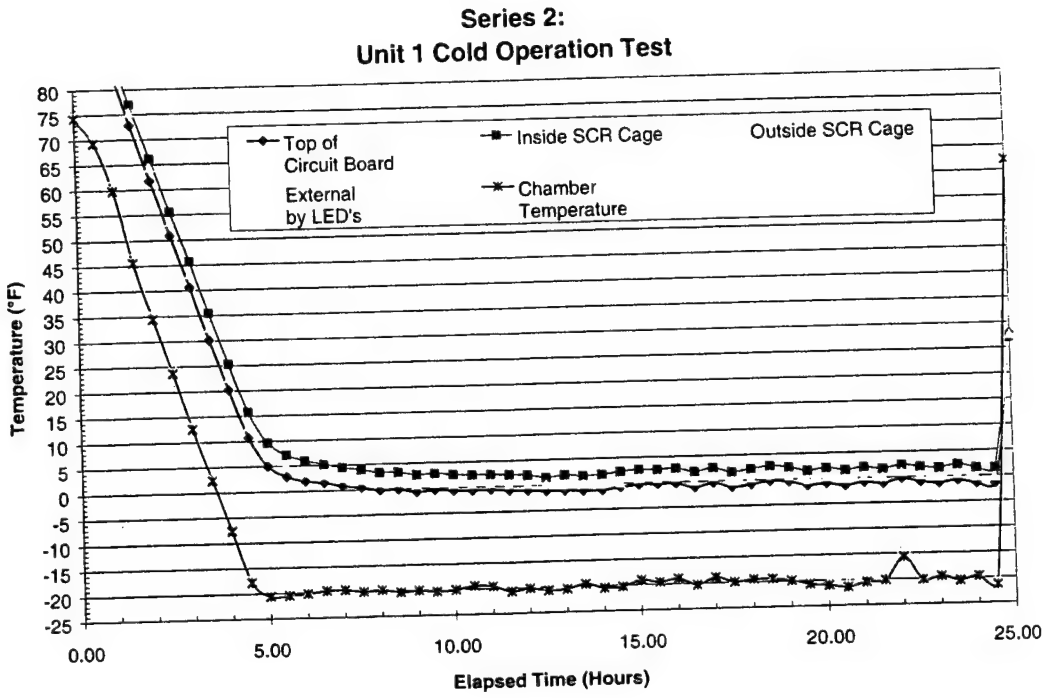
The results of this testing indicate that the units can be made to meet the rain requirements. However, it is important the correct mating connector be used with the appropriate receptacle. Appendix C contains data sheets and test notes that show the functional testing that was performed throughout this test. At the completion of the testing NEDU personnel performed functional testing and the units were found to operate correctly.

5.2.2 Low Temperature Operation

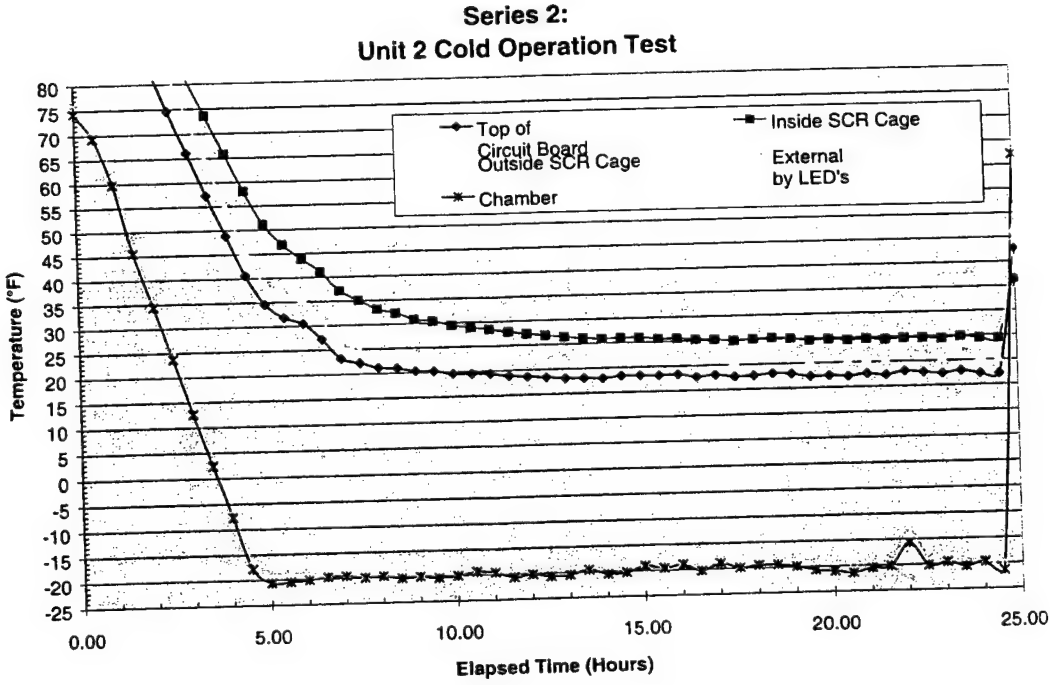
As with the first test series Temperature Operating Tests, the units were placed into the temperature chamber and instrumented with thermocouples. Each unit had thermocouples located as follows: external near the LED and switch panel; on top of the circuit board; inside the SCR chassis; and outside the SCR chassis. In addition, one thermocouple was placed in the air between the two units. For equipment monitoring during the test, a small electric analog clock was plugged into each unit. This provided a small load that could determine operational state of each and could determine, if necessary, the approximate time of failure between operational readings.

The testing was begun on March 17, 2000. The units were preconditioned for approximately 4 hours prior to test start. The operational test was performed the same as for the Series One Temperature Testing. This test was performed for a total of 8 hours. Figure 7 shows the temperature profile for each unit during this test.

The testing was completed with only one minor anomaly. The trip LOW switch for Unit 1 did not always function. Throughout the test it would require depressing the switch 3 or 4 times in order to activate the unit. Once activated, the unit would reset correctly and continued to operate normally. This is the same problem that was observed during the first test series. As with the first test series, this anomaly was not observed in Unit 2. At the completion of the test the switch returned to normal operation. No other anomalies were observed. At the completion of the test, NEDU personnel performed the appropriate functional tests and found the units to be operating correctly.



(a)



(b)

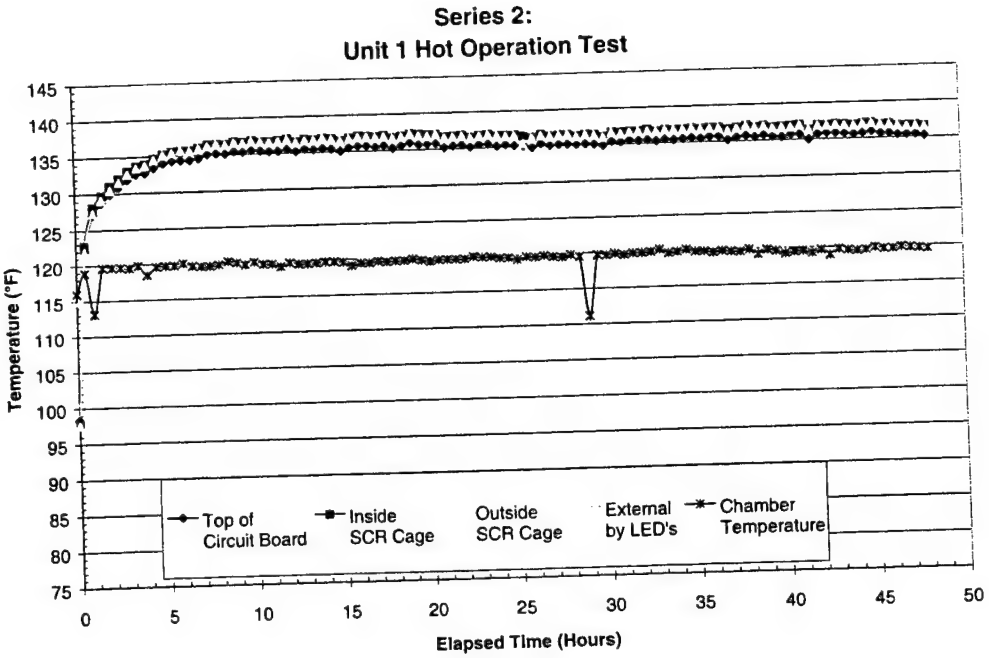
FIGURE 7: Series 2 Temperature profiles for Cold Operation Testing
(a) Unit 1 (b) Unit 2

5.2.3 High Temperature Operation

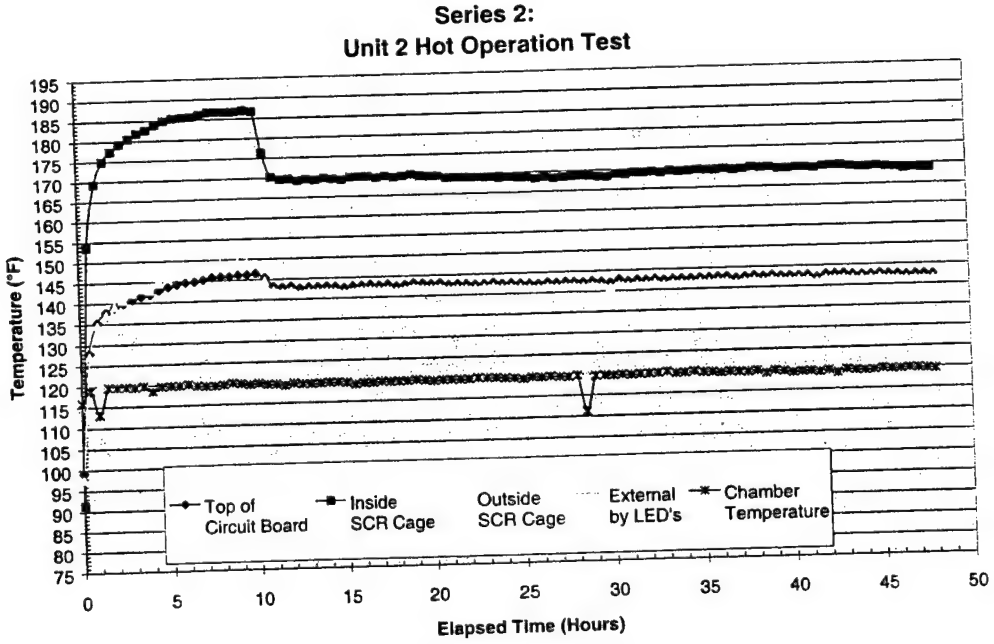
The two units were placed into a temperature chamber and instrumented with thermocouples. Each unit had thermocouples located as follows: external near the LED and switch panel; on top of the circuit board; under the circuit board over the coil; and on the heat sink chassis. In addition, one thermocouple was placed in the air between the two units. For equipment monitoring during the test, a small electric analog clock was plugged into each unit. This provided a small load that could determine the operational state of each and could determine, if necessary, the approximate time of failure between operational readings.

The testing was begun on March 22, 2000. The units were preconditioned to 119°F and maintained for approximately 2 hours prior to starting the test. Once the unit was preconditioned, the operational test was started by manually toggling the "TEST" switch alternately between the "LOW" and "HIGH" positions. The "RESET" switch was manually depressed to reset the unit. This test was repeated approximately once each hour throughout the testing.

The testing was completed on March 24, 2000 with no anomalies observed. Figure 8 shows the temperature profile for each unit over the course of the test. This data indicates that Unit 2 had a slightly higher average internal temperature than Unit 1. The appropriate test data sheets and operational log is included in Appendix C. At the completion of the test, NEDU personnel performed the appropriate functional tests and found the units to be operating correctly.



(a)



(b)

FIGURE 8: Series 2 Temperature profiles for Hot Operation Testing
(a) Unit 1 (b) Unit 2

5.2.4 Vibration

As with the first test series, the vibration test was performed on each unit separately. Each unit was mounted to the vibration table using the same technique as for the Series 1 testing. The vertical, transverse and longitudinal axes were the same as defined for the first series. Therefore, the test profiles used were the same as for Series 1: the profiles defined by MIL-STD-810E, Figure 514.4-1(vertical) and Figure 514.4-3 (longitudinal and transverse).

As with Series 1, two accelerometers were used for control of the test. One accelerometer was located on the vibration table and one accelerometer was located on top of one of the tie down bars. Figure 9 shows the typical responses observed for testing in all three directions. For all plots the center trace is the average of the two accelerometers. The blue (upper) trace is the accelerometer on the table and the green (lower) is on the top of the fixture.

The vibration testing was started on April 5, 2000 and was performed with the unit in the non-operational state. The test was completed in all three directions for one unit with no anomalies. The unit was opened and visually found to be in good condition. However, the main circuit board had loosened significantly. The board was tightened and the powered unit was operated with no change in functional performance. The vibration test was then performed on Unit 2 with similar results. Therefore the GFI units completed this test with no degradation in performance. NEDU personnel performed the functional performance testing with no degradation in performance observed.

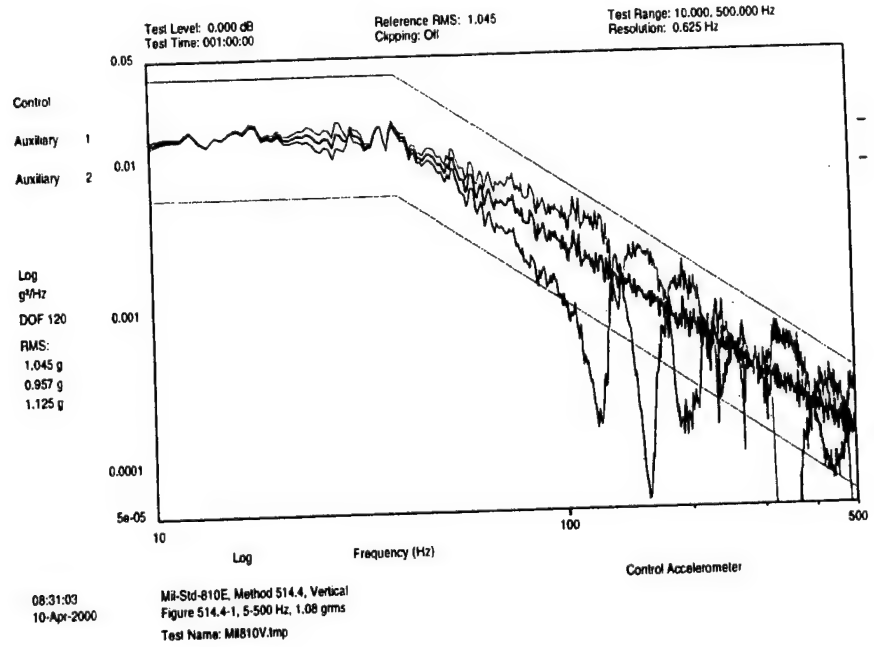


FIGURE 9-A: Typical Series 2 vibration test profiles showing difference between the two control accelerometers for the Vertical Direction

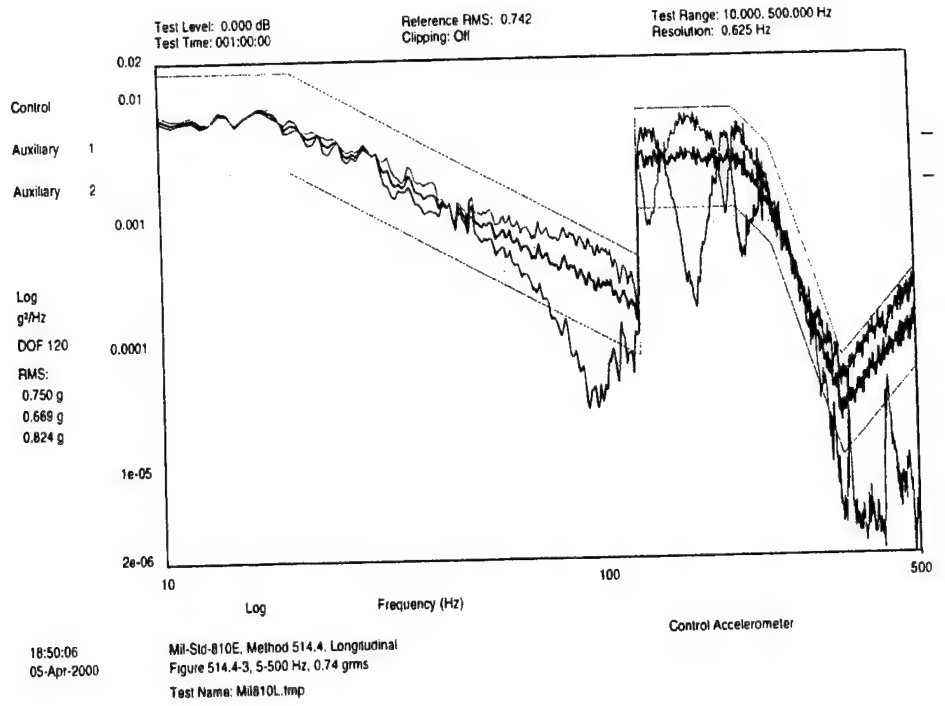


FIGURE 9-B: Typical Series 2 vibration test profiles showing difference between the two control accelerometers for the Longitudinal Direction

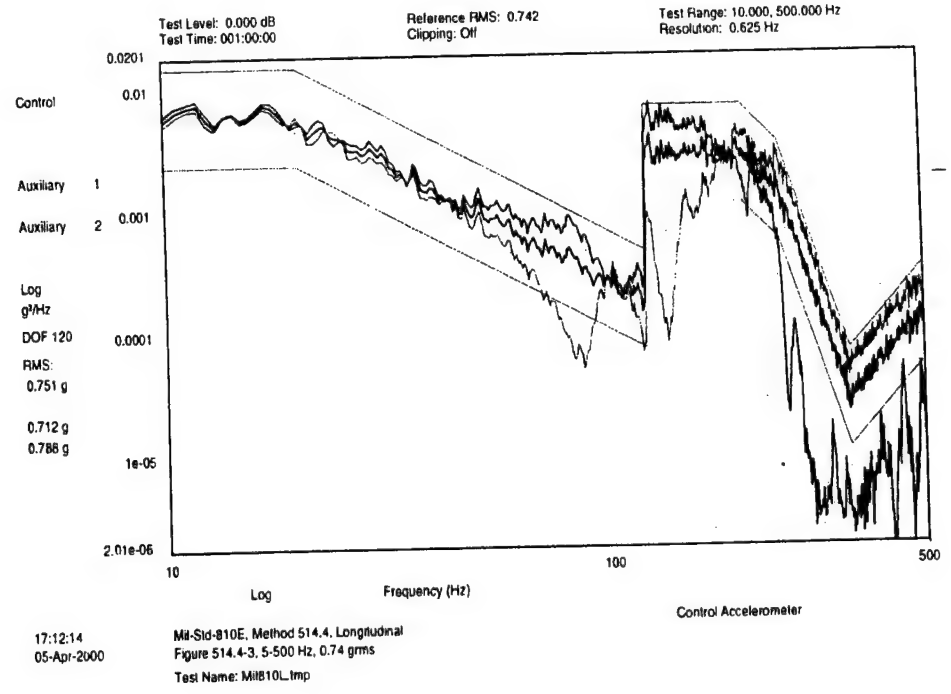


FIGURE 9-C: Typical Series 2 vibration test profiles showing difference between the two control accelerometers for the Transverse Direction

5.2.5 Low Temperature Storage and Transit Drops

The Cold Temperature Storage Test was performed starting on April 10, 2000. The units were placed in a temperature chamber and maintained at –24°F in excess of 20 hours. The units were then powered and tested for function. Both units functioned correctly, with no anomalies observed. The cold soak was then continued for an additional 20 hours, in preparation for the Cold Drops.

On April 12, 2000 the Drop tests were performed. The drop tests consisted of dropping the units from a height of 4 feet onto 2.25 inches of plywood. The plywood was placed on a ½ inch steel plate, which was bolted to a concrete surface. Unit 1 was dropped on all six flat surfaces. Figure 10 shows Unit 1 ready for the first drop.

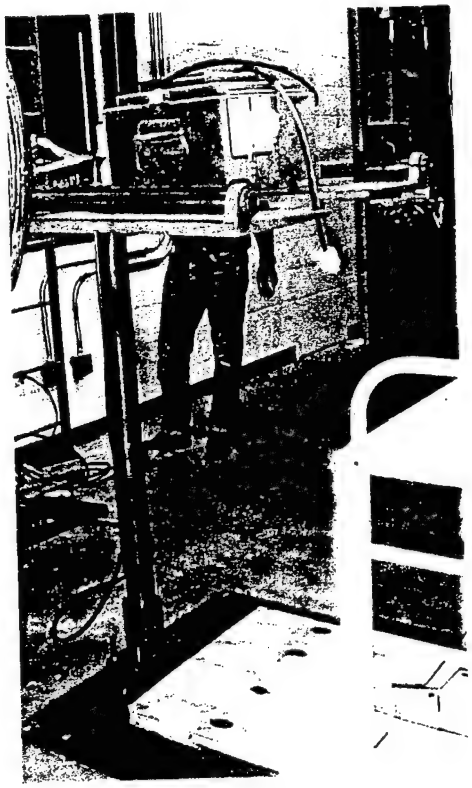


FIGURE 10: Unit 1 ready for drop test on the bottom surface

After each drop, Unit 1 was inspected for visual external damage. Once the damage was noted, the unit was then dropped again. After all drops were completed, the unit was opened and inspected for internal damage. The following chart outlines the damage that was observed for each drop for Unit 1:

Drop Orientation	Description of damage
Bottom	No visible external damage
Left Side	One of the plastic receptacle covers broke off
Right Side	Minor bending of side near metal receptacles
Top	Top Cover Bent
Front End	No visible external damage
Back End	Power cable penetration housing broke

Upon opening Unit 1, it was discovered that the internal connectors to the circuit board had loosened. These were reconnected and the unit was then powered. The unit functioned correctly.

Unit 2 was dropped on six of the eight corners. It was decided to drop the unit on the corners that could potentially cause the most damage. Therefore the unit was dropped on the top four corners and the two corners on the bottom, furthest from the toroidal coil. Figure 10 shows the unit ready for testing in one orientation.

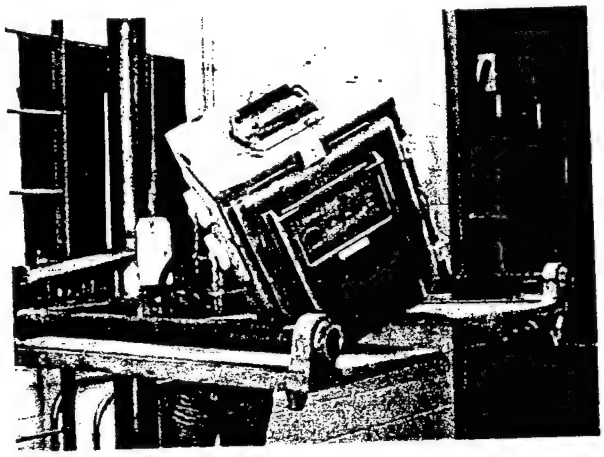


FIGURE 10: Unit 2 ready for the drop on one of the top corners

As with Unit 1, the unit was visually examined after each drop. The only visible external damage was one of the chains connecting the receptacle cover broke. After all the drops were complete the unit was opened and examined for damage. As with Unit 1, all the connectors loosened from the circuit board. However, there was more severe internal damage to this unit. The terminal block and fuse block broke loose as well as a component within the SCR cage. In addition, the insulation on one of the main power wires going to the terminal block was cut away from the wire. Because of the damage, the unit was not powered at the completion of the test.

6.0 Conclusions and Recommendations

The testing was completed with no testing anomalies observed. The results of the testing performed indicate that, with the exception of the transit drops, the units successfully completed the testing. The results of the transit drops indicate that internal damage is likely if the unit is exposed to an extreme dynamic condition. If the unit is exposed to such an event, it is recommended that the unit be inspected internally before putting it into service.

The results of the testing also indicated some areas of concern when considering the operation of the unit. If the unit is to be used in an extreme wet condition, it is extremely important that the load device being used be equipped with the correct mating plug for the receptacle. The water intrusion observed during the Series 2 Rain Test was primarily caused by using the incorrect mating plug with the receptacles.

The test switch on Unit 1 was found to operate intermittently at low temperatures. Due to the low number of samples tested, it is unclear as to if this is a significant problem. It is recommended that this anomaly be considered a minor, single event that applies only to this particular switch.

Maintenance issues were discovered throughout the testing. The internal fuse location made it extremely difficult to replace the fuse. It is recommended that the fuse location be moved to accommodate ease of replacement. In addition, the receptacle mounting holes should be changed. On the current units, the hole is a threaded hole. However, when the new receptacles were installed, some of the holes "stripped". It is therefore recommended that the mounting holes be through holes, with a nut on the inside.

APPENDIX A

TEST PLAN

Test Plan
for Environmental Testing of the
Portable Ground Fault Interrupt Prototype Units

Background

E31 was tasked to provide a test plan for performing Environmental tests for the Portable Ground Fault Interrupt (GFI) units. A meeting was held on Thursday 30 September, 1999 to discuss the desired test program. At that meeting E31 was provided with a list of recommended tests. E31 was tasked to determine the feasibility of performing the tests at CSS, the cost of performing these tests, and any additional test recommendations.

E31 personnel took this information and compiled a recommended testing program. This was submitted to NEDU for evaluation. The basic set of recommendations were incorporated into a required testing program. Based on the discussions, the following is a list of the required tests to be performed:

High Temperature Operation
Low Temperature Operation
Vibration
Rain
Low Temperature Transit Drops

The test procedures for each of these tests are based on recommended procedures found in MIL-STD-810E. The following provides a more detailed description of each environment and will be used at the planned testing for this program.

Functional testing

The units will be functionally tested between each test environment. The test consists of measuring the time from a ground fault condition until the unit power is removed. This test will be performed by NEDU personnel.

High Temperature Operation

This test is based on the requirements of MIL-STD-810E, Method 501.3, Procedure 2. The maximum temperature for this test shall be +48 °C. The unit will be placed in a chamber that is preconditioned to the desired temperature level. Once the unit has stabilized in its operational state, the GFI will be "tripped" manually to the HIGH and LOW trip conditions

The unit will be maintained in the temperature chamber for a total of 48 hours. During this 48 hour period, the GFI will be "tripped" and "reset" a minimum of once every hour.

Low Temperature Operation

The unit will be exposed to the Low Temperature Operation test as specified in MIL-STD-810E, Method 502.3, Procedure II. The unit will be place, in the operational condition within the temperature chamber. The chamber temperature will be lowered to –31 °C stabilized. Once the unit has stabilized, it will be maintained at that temperature for a minimum of 8 hours. During the test, the unit will manually "tripped" and reset as with the High Temperature Operation test. The unit will be "tripped" and reset a minimum of once per hour throughout the test.

Vibration

The vibration test is based on the Transportation Vibration, Common Carrier requirements as specified in MIL-STD-810E, Method 514.4, Category 1, Basic Transportation. The unit, in its shipping and storage container, will be securely mounted to the vibration equipment. The test will be conducted in three mutually perpendicular axis. The test conducted will conform to the specific requirement for each axis as shown in MIL-STD-810E, Figures 514.4-1, 514.4-2, and 514.4-3. The unit will be subjected to the vibration for 60 minutes in each axis for a total test time of 3 hours.

Rain

The rain test is based on the Watertightness Test as specified in MIL-STD-810E, Method 506.3, Procedure III. The GFI will be placed in the test chamber in the upright, operational position, with the required input and output wiring connected. The unit will be operating during the test, and will be manually "tripped" a minimum of once every 20 minutes during the test. The item will be exposed to an overlapping spray pattern where the nozzles are placed 19 inches from the test surface. The droplets will be approximately 2 to 4.5 mm and sprayed at a minimum pressure of 40 psig. The item will be exposed to this environment for a minimum of 40 minutes for each exposed face.

Low Temperature Transient Drop

This test combines the effects of Low Temperature Storage with the potential for being dropped during transit. The unit will be placed within at temperature chamber and maintained at –31 °C for a minimum of 24 hours. After the 24 hours the unit will be subjected to the Transit Drop Test as specified in MIL-STD-810E, Method 516.4, Procedure IV. The unit will be suspended 48 inches above a 2-inch thick plywood surface that is backed by concrete. The unit will be dropped a total of six times, once on each face. A second unit will be dropped on six of eight corners.

APPENDIX B

SERIES 1 TEST DATA SHEETS

SERIES 1: HIGH TEMPERATURE OPERATION
DATA SHEET 1

DATE: Start: 11/04/99 Completed: 11/04/99

1. TEST EQUIPMENT:

Temperature Chamber:	WEBBER Model WF64-100+300 Serial Number: 7894
Temperature Controller:	WATLOW Series 922 Serial Number: 50985
Data Logger:	OMEGA Model OM501-C Serial Number: 48RA263 (M813)

2. THERMOCOUPLE LOCATIONS

EXTERNAL:
Between the two units in chamber air
On top of Unit 1, by the LED's
On top of Unit 2, by the LED's

INTERNAL (Same for Both Units):
Top Center of the circuit board
Under Circuit board, above the main coil
On the SCR heat sink chassis

3. PERFORMANCE DATA

See following Chart for "trip" times during the test. The temperatures were logged on a hard copy every 10 minutes throughout the 48 hour test. These log records are not included with this data sheet, but are maintained by CSS.

Temperature Operation Data Log Sheet						
Date	TIME	Unit 1		Unit 2		Comments
		Low	High	Low	High	
11/4/99	11:00	✓	✓	✓	✓	
	11:47	✓	✓	×	×	Unit 2 not working
	13:38	✓	✓	×	×	Unit 2 not working
	14:00	×	×	×	×	Both units not working, stop test

4. RESULTS/COMMENTS

After approximately 3 hours of testing, both units quit working. The test was discontinued and the units were returned to NEDU for repair.

SERIES 1: HIGH TEMPERATURE OPERATION
DATA SHEET 2

DATE: Start: 11/09/99 Completed: 11/11/99

1. TEST EQUIPMENT:

Temperature Chamber:	WEBBER Model WF64-100+300 Serial Number: 7894
Temperature Controller:	WATLOW Series 922 Serial Number: 50985
Data Logger:	OMEGA Model OM501-C Serial Number: 48RA263 (M813)

2. THERMOCOUPLE LOCATIONS

EXTERNAL:
Between the two units in chamber air
On top of Unit 1, by the LED's
On top of Unit 2, by the LED's

INTERNAL (Same for Both Units):
Top Center of the circuit board
Under Circuit board, above the main coil
On the SCR heat sink chassis

3. PERFORMANCE DATA

See attached chart for "trip" times during the test. The temperatures were logged on a hard copy every 10 minutes throughout the 48 hour test. These log records are not included with this data sheet, but are maintained by CSS.

4. RESULTS/COMMENTS

Both units completed this test with no anomalies observed.

Series 1: Hot Temperature Operation Performance Data Log

Temperature Operation Data Log Sheet						
Date	TIME	Unit 1		Unit 2		Comments
		Low	High	Low	High	
11/9/99	9:18	✓	✓	✓	✓	Chamber Started
	10:09	✓	✓	✓	✓	
	10:43	✓	✓	✓	✓	Plugged in Clocks
	11:45	✓	✓	✓	✓	
	12:15	✓	✓	✓	✓	
	13:06	✓	✓	✓	✓	
	14:12	✓	✓	✓	✓	
	15:03	✓	✓	✓	✓	
	15:43	✓	✓	✓	✓	
	16:11	✓	✓	✓	✓	
	17:03	✓	✓	✓	✓	
	18:00	✓	✓	✓	✓	
	19:00	✓	✓	✓	✓	
	20:03	✓	✓	✓	✓	
	20:35	✓	✓	✓	✓	
	21:27	✓	✓	✓	✓	
	22:15	✓	✓	✓	✓	
	22:55	✓	✓	✓	✓	
	23:48	✓	✓	✓	✓	
11/10/00	0:40	✓	✓	✓	✓	
	1:30	✓	✓	✓	✓	
	2:20	✓	✓	✓	✓	
	3:27	✓	✓	✓	✓	
	4:28	✓	✓	✓	✓	
	5:43	✓	✓	✓	✓	
	6:50	✓	✓	✓	✓	
	7:48	✓	✓	✓	✓	
	8:52	✓	✓	✓	✓	
	9:45	✓	✓	✓	✓	
	10:38	✓	✓	✓	✓	
	11:53	✓	✓	✓	✓	
	13:15	✓	✓	✓	✓	
	14:20	✓	✓	✓	✓	
	14:50	✓	✓	✓	✓	
	15:40	✓	✓	✓	✓	
	16:15	✓	✓	✓	✓	
	16:55	✓	✓	✓	✓	
	17:40	✓	✓	✓	✓	
	18:40	✓	✓	✓	✓	
	19:42	✓	✓	✓	✓	
	20:47	✓	✓	✓	✓	
	22:15	✓	✓	✓	✓	
	22:44	✓	✓	✓	✓	
	23:25	✓	✓	✓	✓	

Temperature Operation Data Log Sheet						
Date	TIME	Unit 1		Unit 2		Comments
		Low	High	Low	High	
11/11/99	0:08	✓	✓	✓	✓	
	0:55	✓	✓	✓	✓	
	1:45	✓	✓	✓	✓	
	2:25	✓	✓	✓	✓	
	3:03	✓	✓	✓	✓	
	4:00	✓	✓	✓	✓	
	5:05	✓	✓	✓	✓	
	6:00	✓	✓	✓	✓	
	7:00	✓	✓	✓	✓	
	8:15	✓	✓	✓	✓	
	9:00	✓	✓	✓	✓	Test Stopped

SERIES 1: LOW TEMPERATURE OPERATION
DATA SHEET

DATE: Start: 11/19/99 Completed: 11/19/99

1. TEST EQUIPMENT:

Temperature Chamber:	WEBBER Model WF64-100+300 Serial Number: 7894
Temperature Controller:	WATLOW Series 922 Serial Number: 50985
Data Logger:	OMEGA Model OM501-C Serial Number: 48RA263 (M813)

2. THERMOCOUPLE LOCATIONS

EXTERNAL:
Between the two units in chamber air
On top of Unit 1, by the LED's
On top of Unit 2, by the LED's

INTERNAL (Same for Both Units):
Top Center of the circuit board
Under Circuit board, above the main coil
On the SCR heat sink chassis

3. PERFORMANCE DATA

See attached chart for "trip" times during the test. The temperatures were logged on a hard copy every 10 minutes throughout the 8 hour test. These log records are not included with this data sheet, but are maintained by CSS.

4. RESULTS/COMMENTS

Both units completed this test with one minor anomaly observed. Unit 1 "LOW" trip switch did not operate correctly every time. It would require toggling the switch several times before a trip condition was initiated. The switch returned to normal operation once the unit was returned to room temperature.

Series 1: Cold Temperature Operation Performance Data Log

Temperature Operation Data Log Sheet						
Date	TIME	Unit 1		Unit 2		Comments
		Low	High	Low	High	
11/19/99	19:00	×	✓	✓	✓	Low Trip intermittent
	20:00	×	✓	✓	✓	"
	21:00	×	✓	✓	✓	"
	22:30	×	✓	✓	✓	"
	23:00	×	✓	✓	✓	"
	23:30	×	✓	✓	✓	"
	0:30	×	✓	✓	✓	"
	1:00	×	✓	✓	✓	"
	2:00	×	✓	✓	✓	"
	3:00	×	✓	✓	✓	"

SERIES 1: VIBRATION DATA SHEET

DATE: Start: 12/01/99 Completed: 12/03/99

1. TEST EQUIPMENT:

Vibration Table:	UNHOLTZ-DICKIE Model TC208 Shaker Serial Number: 508
Vibration Controller:	SPECTRAL DYNAMICS Model 2552C Serial Number: 7894
Accelerometers:	DYTRAN Model 3152C Serial Numbers: 1199 & 1200
Charge Amplifier:	DYTRAN Model 4705A3 Serial Numbers: 1404 & 1405
Power Supply/Conditioner:	DYTRAN Model 4121 Serial Number 286

2. ACCELEROMETER LOCATIONS

Only two accelerometers were used for this test and both were used for feedback control of the acceleration. One accelerometer was located on the vibration table, near the GFI mounting location. The second accelerometer was located on the tie down bar used on top of the GFI. The average of the two accelerations were used as the method of obtaining the desired acceleration levels. No internal accelerations were measured during this test.

3. PERFORMANCE DATA

This test was performed with the unit in the non-operational state. Therefore no performance data was collected during the test. To aid in test setup, the test was performed in one direction for each unit. Each unit was then reoriented and the test was performed for the next orientation.

4. RESULTS/COMMENTS

At the completion of 3 directions of testing for Unit 1, the functional test was attempted. The unit failed to operate. The unit was opened and two of the connectors to the circuit board were loose. They were reconnected and the unit returned to normal operation.

Upon discovering the loose connectors, it was decided to halt the test in the third direction for Unit 2 in order to visually inspect the connectors. This unit also had loose connectors. The connectors were reconnected and the unit was fully operational. The final direction of testing was then performed. Final inspection of the unit at the completion of this test revealed that the connectors had again loosened. The connectors were reconnected and the unit was fully operational.

SERIES 1: RAIN TEST DATA SHEET

DATE: Start: 12/07/99 Completed: 12/10/00

1. TEST EQUIPMENT:

The rain test equipment consisted of 5 shower heads arranged in an "H" pattern. A single ¾ inch hose supplied tap water to the heads. This equipment was made by CSS.

2. INSTRUMENTATION

No instrumentation was used for this test.

3. PERFORMANCE DATA

The unit was successfully "tripped" and "reset" approximately once every 20 minutes throughout the testing. However, a log sheet logging the times was not kept and is therefore not available.

4. RESULTS/COMMENTS

Unit 1 was tested in 3 orientations for 40 minutes in each direction. At the completion of the test, the unit was opened and visually inspected. Upon opening, it was discovered that the bottom of the unit was completely covered to a depth of approximately ¼ inch.

Unit 2 was tested in 1 orientation for 40 minutes. The orientation chosen was the side with the load plugged in (worst case). At the end of 40 minutes, the unit was opened and visually inspected. Approximately 1/8 inch of water was discovered in the bottom of the unit.

Because of the amount was water intrusion, it was decided to discontinue testing. The units were returned to NEDU and no further testing was performed.

APPENDIX C

SERIES 2 TEST DATA SHEETS

SERIES 2: RAIN TEST DATA SHEET

DATE: Start: 3/07/00 Completed: 3/15/00

5. TEST EQUIPMENT:

The rain test equipment consisted of 5 shower heads arranged in an "H" pattern. A single ¾ inch hose supplied tap water to the heads. This equipment was made by CSS.

6. INSTRUMENTATION

No instrumentation was used for this test.

7. PERFORMANCE DATA

The unit was "tripped" approximately once every 10 minutes throughout the testing. The attached log sheets show the "trip" times throughout the testing.

8. TEST ORIENTATIONS

The unit was placed flat on the bottom
The unit was tilted on one side with a load plugged into the raised side
The unit was tilted on the other side with a load plugged into the lower side

9. RESULTS/COMMENTS

Unit 1 was tested in 3 orientations for 40 minutes in each direction. At the completion of the test, the unit was opened and visually inspected. Upon opening, it was discovered that unit contained approximately 2-3 ounces of water.

Unit 2 was tested in 1 orientation for 40 minutes. During the second orientation, the unit tripped. The unit was reset, and the tilt angle was reduced. The unit "tripped" again. This was repeated until the unit could no be reset. A blown fuse was discovered. In addition approximately 1 to 2 ounces of water was inside.

Because of the water intrusion, several different tests were performed to determine the cause of the water intrusion. The data log sheets provide a detailed description as to the various tests performed and the results of each.

The results of the additional testing indicated that the units could successfully complete the rain test. This could only be accomplished when the appropriate mating connector was used with the watertight receptacles.

Rain Test Data Log Sheet

Rain Test Data Log Sheet				
Date	TIME	Unit 2		Comments/Configuration
		Low	High	
3/7/00	13:16	✓	✓	Power On - Orientation 1: Bottom, light plugged into Right Side inner socket
	13:18			Water On
	13:28	✓	✓	"
	13:38	✓	✓	"
	13:48	✓	✓	"
	13:56	✓	✓	"
	13:58			Water off
	14:01	✓	✓	Water On - Oreintation 2: Right Side tilted up, light plugged into Right Side inner socket
	14:11	✓	✓	"
	14:21	✓	✓	"
	14:31	✓	✓	"
	14:38	✓	✓	"
	14:41	✓	✓	Water Off
	14:56	✓	✓	Water On - Oreintation 3: Left Side tilted up, light plugged into Right Side inner socket
	15:06	✓	✓	"
	15:16	✓	✓	"
	15:26	✓	✓	"
	15:34	✓	✓	"
	15:36			Water off
	15:38	✓	✓	Water On - Oreintation 4: Front Side (power feed end) tilted up, light plugged into Right Side inner socket
	15:48	✓	✓	"
	15:58	✓	✓	"
	16:08	✓	✓	"
	16:16	✓	✓	"
	16:18			Water off

Rain Test Data Log Sheet				
Date	TIME	Unit 1		Comments/Configuration
		Low	High	
3/8/00	7:01	✓	✓	Power On - Orientation 1: Bottom
	7:02			Water On
	7:11	✓	✓	"
	7:21	✓	✓	"
	7:31	✓	✓	"
	7:36	✓	✓	"
	7:41			Water off
	7:43	✓	✓	Water On - Oreintation 2: Right Side tilted up, light plugged into Right Side inner socket
	7:43			Unit tripped
	7:45	✓	✓	Test restart after repositioning to a Lower angle
	7:47			Unit tripped
	7:56	✓	✓	
	7:58			Unit tripped
	7:59	✓	✓	Test restart after repositioning to a Lower angle
	8:00			Unit tripped
	8:01	✓	✓	Restart
	8:02			Unit tripped
	8:03	✓	✓	Test restart after repositioning to a Lower angle
	8:03			Unit tripped and could not reset

Rain Test Additional Test Data Sheet
Chronology of Events

A. 3/08/99

Test 1: Unit 1 was tested with nothing plugged into the outlets and all the receptacle caps were screwed in place. The unit was flat on the bottom. The test was run for a total of 40 minutes. At the completion of the 40 minutes the unit was opened and found to be dry.

B. 3/09/00

Test 2: A shroud was placed over the load wire and receptacle housing for Unit 1. The unit was oriented with the right side tilted up. Approximately 36 minutes into the test, the unit tripped off. The unit was opened and found to contain approximately 2-3 ounces of water. When the shroud was removed, a small pool of water was in the bottom of the receptacle housing.

Reconfigure: A new rubber receptacle and mating plug was provided. This receptacle was retrofitted into the two units. Unit 1 received one of these and Unit 2 was retrofitted with two.

C. 3/10/00

Test 3: Unit 1 was set up for the rain test by plugging a load (light) with the proper connector installed into the new receptacle. A test was run with the unit flat on the bottom. At the completion of 40 minutes, the unit was opened and inspected. No visible signs of water intrusion were noted. The test was repeated with the unit oriented with the right side up. Again no signs of water intrusion were evident at the completion of the test.

Test 4: Unit 2 was set up for a test with all receptacles covered. However, when tripped low, the unit would not reset. Several attempts were made at correcting the problem, with no success. The test was halted until a copy of the schematics could be obtained to further troubleshoot the problem.

D: 3/13/00- 3/14/00

Repairs: The problem with Unit 2 was further investigated once a set of schematics were obtained. Since an operational unit was also available, it was used to compare voltages at various locations on the circuit boards. Through this process, it was discovered that a capacitor (C24) was bad. This part was replaced and the unit returned to normal operation.

E. 3/15/00

Test 5: Unit 2 was setup for the rain test with nothing plugged in. The unit was oriented flat on the bottom. The unit was exposed to the rain test for a total of 40 minutes. The unit was then opened and inspected. No visible evidence of water intrusion was observed. The test was repeated with the right side tilted up, with the same result.

Test 6: Unit 1 was tested again. This time the load plug was equipped with a mating boot connector, designed to work with the manufacturer installed GFI receptacles. The test was performed for 40 minutes with the unit flat on the bottom. At the completion of the test, the unit was opened and no evidence of water intrusion was observed. This test was repeated with the connector side tilted up toward the spray. At the completion of the 40 minutes of "rain", the unit was opened and inspected. No evidence of water intrusion was observed.

SERIES 2: LOW TEMPERATURE OPERATION
DATA SHEET

DATE: Start: 3/17/00 Completed: 3/17/00

5. TEST EQUIPMENT:

Temperature Chamber:	WEBBER Model WF64-100+300 Serial Number: 7894
Temperature Controller:	WATLOW Series 922 Serial Number: 50985
Data Logger:	OMEGA Model OM501-C Serial Number: 48RA263 (M813)

6. THERMOCOUPLE LOCATIONS

EXTERNAL:
Between the two units in chamber air
On top of Unit 1, by the LED's
On top of Unit 2, by the LED's

INTERNAL (Same for Both Units):
Top Center of the circuit board
Inside the SCR chassis
On the SCR heat sink chassis

7. PERFORMANCE DATA

See following Chart for "trip" times during the test. The temperatures were logged on a hard copy every 15 minutes throughout the 8 hour test. These log records are not included with this data sheet, but are maintained by CSS.

8. RESULTS/COMMENTS

Both units completed this test with one minor anomaly observed. Unit 1 "LOW" trip switch did not operate correctly every time. It would require toggling the switch several times before a trip condition was initiated. The switch operated normally once the unit was returned to room temperature.

Series 2: Cold Temperature Operation Performance Data Log

Temperature Operation Data Log Sheet						
Date	TIME	Unit 1		Unit 2		Comments
		Low	High	Low	High	
3/17/00	7:05	✓	✓	✓	✓	
	7:48	✓	✓	✓	✓	
	8:18	✓	✓	✓	✓	
	8:49	✓	✓	✓	✓	
	9:50	x	✓	✓	✓	Unit 1, Low Trip intermittent
	10:44	✓	✓	✓	✓	Both units ok
	11:18	x	✓	✓	✓	Unit 1, Low Trip intermittent
	11:50	x	✓	✓	✓	"
	12:33	x	✓	✓	✓	"
	13:37	x	✓	✓	✓	"
	14:38	x	✓	✓	✓	"
	14:58	x	✓	✓	✓	"
	16:00	x	✓	✓	✓	"
	17:30	x	✓	✓	✓	"
	18:15					GFI units Turned Off, Chamber turned off

SERIES 2: HIGH TEMPERATURE OPERATION
DATA SHEET

DATE: Start: 3/22/00 Completed: 3/24/00

9. TEST EQUIPMENT:

Temperature Chamber:	WEBBER Model WF64-100+300 Serial Number: 7894
Temperature Controller:	WATLOW Series 922 Serial Number: 50985
Data Logger:	OMEGA Model OM501-C Serial Number: 48RA263 (M813)

10. THERMOCOUPLE LOCATIONS

EXTERNAL:
Between the two units in chamber air
On top of Unit 1, by the LED's
On top of Unit 2, by the LED's

INTERNAL (Same for Both Units):
Top Center of the circuit board
Inside the SCR chassis
On the SCR heat sink chassis

11. PERFORMANCE DATA

See following Chart for "trip" times during the test. The temperatures were logged on a hard copy every 15 minutes throughout the 8 hour test. These log records are not included with this data sheet, but are maintained by CSS.

12. RESULTS/COMMENTS

Both units completed this test with no anomalies observed.

Series 2: Hot Temperature Operation Performance Data Log

Temperature Operation Data Log Sheet						
Date	TIME	Unit 1		Unit 2		Comments
		Low	High	Low	High	
3/22/00	9:39	✓	✓	✓	✓	Chamber Started
	10:36	✓	✓	✓	✓	
	11:16	✓	✓	✓	✓	
	13:25	✓	✓	✓	✓	
	14:04	✓	✓	✓	✓	
	14:17	✓	✓	✓	✓	
	15:16	✓	✓	✓	✓	
	15:56	✓	✓	✓	✓	
	16:30	✓	✓	✓	✓	
	17:15	✓	✓	✓	✓	
	18:01	✓	✓	✓	✓	
	18:47	✓	✓	✓	✓	
	19:40	✓	✓	✓	✓	
	20:25	✓	✓	✓	✓	
	21:00	✓	✓	✓	✓	
	22:00	✓	✓	✓	✓	
	22:50	✓	✓	✓	✓	
	23:50	✓	✓	✓	✓	
3/23/00	0:25	✓	✓	✓	✓	
	1:00	✓	✓	✓	✓	
	1:40	✓	✓	✓	✓	
	2:10	✓	✓	✓	✓	
	3:20	✓	✓	✓	✓	
	3:54	✓	✓	✓	✓	
	4:46	✓	✓	✓	✓	
	5:42	✓	✓	✓	✓	
	6:29	✓	✓	✓	✓	
	7:10	✓	✓	✓	✓	
	8:01	✓	✓	✓	✓	
	8:44	✓	✓	✓	✓	
	9:20	✓	✓	✓	✓	
	10:08	✓	✓	✓	✓	
	10:58	✓	✓	✓	✓	
	11:28	✓	✓	✓	✓	
	12:21	✓	✓	✓	✓	
	13:20	✓	✓	✓	✓	
	14:06	✓	✓	✓	✓	

Temperature Operation Data Log Sheet						
Date	TIME	Unit 1		Unit 2		Comments
		Low	High	Low	High	
3/23/00	15:28	✓	✓	✓	✓	
	16:17	✓	✓	✓	✓	
	16:22	✓	✓	✓	✓	
	17:22	✓	✓	✓	✓	
	18:30	✓	✓	✓	✓	
	19:24	✓	✓	✓	✓	
	20:00	✓	✓	✓	✓	
	20:55	✓	✓	✓	✓	
	22:30	✓	✓	✓	✓	
	23:05	✓	✓	✓	✓	
	23:40	✓	✓	✓	✓	
3/24/00	0:00	✓	✓	✓	✓	
	0:45	✓	✓	✓	✓	
	1:20	✓	✓	✓	✓	
	2:20	✓	✓	✓	✓	
	3:00	✓	✓	✓	✓	
	4:05	✓	✓	✓	✓	
	5:00	✓	✓	✓	✓	
	5:45	✓	✓	✓	✓	
	6:44	✓	✓	✓	✓	
	7:45	✓	✓	✓	✓	
	8:45	✓	✓	✓	✓	
	9:52	✓	✓	✓	✓	
	10:00					Test Stopped

SERIES 1: VIBRATION DATA SHEET

DATE: Start: 4/5/00 Completed: 4/10/00

5. TEST EQUIPMENT:

Vibration Table:	UNHOLTZ-DICKIE Model TC208 Shaker Serial Number: 508
Vibration Controller:	SPECTRAL DYNAMICS Model 2552C Serial Number: 7894
Accelerometers:	DYTRAN Model 3152C Serial Numbers: 1199 & 1200
Charge Amplifier:	DYTRAN Model 4705A3 Serial Numbers: 1404 & 1405
Power Supply/Conditioner:	DYTRAN Model 4121 Serial Number 286

6. ACCELEROMETER LOCATIONS

Only two accelerometers were used for this test and both were used for feedback control of the acceleration. One accelerometer was located on the vibration table, near the GFI mounting location. The second accelerometer was located on the tie down bar used on top of the GFI. The average of the two accelerations were used as the method of obtaining the desired acceleration levels. No internal accelerations were measured during this test.

7. PERFORMANCE DATA

This test was performed with the unit in the non-operational state. Therefore no performance data was collected during the test. To aid in test setup, the test was performed in one direction for each unit. Each unit was then reoriented and the test was performed for the next orientation.

8. RESULTS/COMMENTS

At the completion of the test, the units were opened and visually inspected. In both units the main PC board was found to have loosened significantly. The board was tightened and the units were functionally tests. The units were found to operate correctly.

SERIES 2: LOW TEMPERATURE STORAGE AND TRANSIENT DROP
DATA SHEET

DATE: Start: 4/10/00 Completed: 4/12/00

1. TEST EQUIPMENT:

Temperature Chamber:	WEBBER Model WF64-100+300 Serial Number: 7894
Temperature Controller:	WATLOW Series 922 Serial Number: 50985
Drop Tester:	GAYNES ENGINEERING Model 04 Serial Number: 4873

2. INSTRUMENTATION LOCATION

These tests did not require any instrumentation on the unit. The temperature was maintained by the chamber thermocouples that the temperature controller uses for feedback control. A Honeywell circular chart recorder was used to record the temperatures during the storage times.

3. PERFORMANCE DATA

This test was performed with the unit in the non-operational state. Therefore there is no performance data that was collected. Temperature charts, maintained by CSS, show that the temperature was adequately maintained at –24 °F for the duration of the storage time. The drop height was measured at 4 feet. The impact surface was a 2.25 inch plywood block, that was placed onto a ½ inch steel plate, that is bolted, in the corners to a concrete floor.

4. RESULTS/COMMENTS

The units were maintained for over 20 hours at –24°F . At the end of the 20 hour period, the units were functionally tested. The units were found to operate correctly. The units were returned to the temperature chamber and maintained for an additional 20 hours at –24 °F. After the 20 hour period, the units were individually removed from the temperature chamber for the performance of the drops. The time from the start of drops to the completion of the drops was approximately 30 minutes.

Unit 1 was dropped on all six flat surfaces. Some exterior damage was noted and is included in the attached test log. After all the drops were completed, the unit was opened and examined for internal damage. Several internal connections were found to be loose. Once the connections were restored, the unit was powered and found to be operating correctly.

Unit 2 was dropped on six of eight corners. The unit was dropped on the top 4 corners and on the two bottom corners, furthest from the coil. Only minor exterior damage was noted, most notably being denting of the corners. After all drops were completed, the unit was opened and examined. There were several items that were found to be broken or loose. These findings are listed in the attached test log. Due to the severity of the damage, the unit was not powered or functioned at the completion of the test.

TRANSIENT DROP TEST LOG

UNIT 1:

External Observations

Drop 1: Flat on the bottom - No significant external damage observered
Drop 2; Flat on Left Side – One of the plastic receptacle covers broke off.
Drop 3: Flat on right side – Minor bending of the side, near metal receptacles.
Drop 4: Flat on the top – The top cover bent. Observation of the drop indicated that the unit did not land perfectly flat, which could have caused the bending.
Drop 5: Flat on Front end – No visible external damage was noted.
Drop 6: Flat on the Back end - The power cable penetration housing broke

Internal Observations

Internal connections to the main circuit were disconnected. They were replaced. No other internal damage was observed.

UNIT 2:

External Observations

Drops 1- 4 : Each drop on one of the 4 top corners. - No significant damage noted for any drop. Minor denting of each corner occurred.
Drops 5 & 6: Bottom corners, furthest from coil – No significant damage noted for any drop. Minor denting of each corner occurred. One of the chains retaining a receptacle cover broke.

Internal Observations:

a. The internal connectors that attach the various wire bundles to the circuit boards were loose.
b. A component within the SCR chassis broke loose
c. The main terminal block broke loose
d. The fuse block broke loose
e. The insulation on one of the main power wires going to the terminal block was cut away from the wire.

Due to the observed internal damage, the unit was not powered.